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Defense Portfolio Analysis

By: Albert Adams,
Eric Bala,
Bill Minner, and
Tom Woodland

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Advisors: Raymond E. Franck
Johnathan Mun

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Monterey, CA 93943-5000

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This project paper provides a systematic decomposition and industrial comparison of the U.S. defense decision-support process methodologies of *Portfolio Analysis* (PA). Included are current methods, tools, and models for ranking and evaluating strategic alternatives and options. The PA *decision-support process* analyzed in the study is used by the Department of Defense (DoD) to allocate resources to satisfy national strategic goals. Our working premise is that an effective *decision-support process* provides data driven knowledge directly to relevant decision makers to meet *all* U.S. defense and national strategic requirements, including proper balance of costs, risks, and capabilities in both routine operational and tactical battle space scenarios. To conduct this evaluation (4) Program Management (PM) and 2 PA tools were researched with a view to modeling identifiable strategic requirements juxtaposed with technical, financial, and implementation factors to meet today's strategic capabilities requirements. What was learned is that together PA and PM tools used correctly provide useful tools for decision makers at all levels of government provided they are used correctly. While utilizing the modeling programs, experts in strategic and program analysis need to evaluate acquisition programs to rate the potential Estimated Military Value (EMV) in meeting the strategic needs of the United States.

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DEFENSE PORTFOLIO ANALYSIS

Albert Adams
Civilian, Department of the Army
B.S., Virginia State University, 1989

Eric Bala
Civilian, Department of the Navy
B.S., Coleman College, 1985

William Minner
Civilian, Department of the Army
B.A., St. Leo University, 1998

Thomas Woodland
Civilian, Department of the Navy
B.S., University of Maryland, 1990

Submitted in partial fulfillment of the requirements for the degree of

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June 2009

Authors: ____
Albert Adams

____
Eric Bala

____
William Minner

____
Thomas Woodland

Approved by: ____
Raymond E. Franck, PhD, Advisor

____
Jonathan Mun, PhD, Advisor

____
Bill Gates, Dean
Graduate School of Business and Public Policy

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To conduct this evaluation (4) Program Management (PM) and 2 PA tools were researched with a view to modeling identifiable strategic requirements juxtaposed with technical, financial, and implementation factors to meet today's strategic capabilities requirements. What was learned is that together PA and PM tools used correctly provide useful tools for decision makers at all levels of government provided they are used correctly. While utilizing the modeling programs, experts in strategic and program analysis need to evaluate acquisition programs to rate the potential Estimated Military Value (EMV) in meeting the strategic needs of the United States.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

C/G	COTS/GOTS
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CoE	Center of Excellence
COTS	Commercial Off-the-Shelf
C/G	COTS/GOTS
C2	Command and Control
DFAS	Defense Finance and Accounting Service
DoD	Department of Defense
DoN	Department of the Navy
EMV	Expected Military Value
FTE	Full Time Equivalent
FY	Fiscal Year
GAO	Government Accounting Office
GOTS	Government Off-the-Shelf
IRM	Integrated Risk Management
IT	Information Technology
JCIDS	Joint Capabilities Integration Development System
KVA	Knowledge Value Added
MCM	Mine Countermeasures
MRL	Manufacturing Readiness Level
MVO	Mean-Variance Optimization
NCW	Net-Centric Warfare
NDS	National Defense Strategy
NPS	Naval Postgraduate School
NPV	Net Present Value
OPPS	Office Project Portfolio Server
O&S	Operations and Support
PA	Portfolio Analysis
PMA	Portfolio Management Analysis
PBL	Performance Based Logistics
PfM	Portfolio Management
PM	Program Management
PPM	Project Portfolio Management
RDT&E	Research, Development, Test & Evaluation
ROA	Real Options Analysis
ROI	Return On Investment
SE	Systems Engineering
SECDEF	Secretary of Defense
SME	Subject Matter Expert
TRL	Technology Readiness Level
VaR	Value at Risk

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EXECUTIVE SUMMARY

This is a Portfolio Management Analysis assessment was conducted from August 2008 through May 2009. The focus of this Joint Applied Project is identify and assess current Commercial Off-the-Shelf (COTS) Portfolio Analysis (PA) software products and solutions—with attention to market positioning, market share, product features, and other features. Two products (Risk Simulator and Palisades @Risk) were used to develop Portfolio Models. These models were populated with relevant data, and then run through an appropriate number simulation iterations to assess candidate projects with respect to risk and Expected Military Value (EMV).

This document discusses Portfolio Management Analysis (PMA) during various stages of project management and system engineering. The goal for PMA is realized after the entire project design infrastructure is implemented from agency heads to managers and the end users instruments are provided for implementation.

PMA requirements and scaling become secondary to the general strategic design and fit of each organization. Even where there is a lack of desired leadership, organizations should implement best practices and tools found in successful Portfolio Management Projects. This foundation enables organizational growth by providing design tools to achieve scalable requirements, operational readiness and the functions needed to provide sound balance business practices. However, broad PA implementation could more likely be slowed by policy, management and funding constraints, rather than technical considerations.

We found that notwithstanding a need for some caution; PA tools are a way of enriching and equipping Department of Defense (DoD) communities with a means of professionally managing their resources. However, agencies and managers must balance new DoD Acquisition, Technology and Logistics Life Cycle Management Strategic Portfolio Development policies, as directed by Congress. Working PA tools at this level requires policy that ensures proper budget and program identification of existing or legacy, evolutionary or new development. The results of this analysis will be synthesized, documented and recommended to defense military organizations, and

agency heads for consideration. The intent is to identify approaches and tools to incorporate PMA net-centric strategies to meet war fighter and business operations requirements, while continuing to maintain current levels of service, ensuring conservation of manpower and meeting infrastructure resource requirements.

Key Recommendations

1. Develop PA education programs.
2. Develop a PA solutions and interoperability lab.
3. Develop a PA Center of Excellence (CoE). The authors feel Naval Postgraduate School (NPS) is ideally suited to develop the curriculum, lab, CoE, and training programs. In short, NPS is well suited to provide a "PA Solution Center" within DoD.

I. U.S. DEFENSE PORTFOLIO ANALYSIS

A. PORTFOLIO ANALYSIS

This chapter defines and describes PA; where it started, what it measures, how other industries are utilizing it, why it is important today, and what the DoD is doing and planning for the future.

Modern Portfolio Theory was introduced by Harry Markowitz with his paper "Portfolio Selection," which appeared in the *Journal of Finance* (1952). He demonstrated that a portfolio of individual securities composed of consistently good risk-reward characteristics (e.g., stocks of all rail companies), could well be foolish. He detailed the mathematics of diversification, which focused on selecting portfolios based on their overall risk-reward characteristics. He felt that investors should create portfolios of dissimilar securities rather than purchase and hold only individual securities (e.g., only shares of IBM). Portfolio theory provides a broad context for understanding the interactions of systematic and non-systematic risk and reward.

Non-systematic risk (diversifiable) is specific to a particular security or sector so that the impact on a diversified portfolio is limited. This indicates that DoD strategic decision makers must not place all their assets (securities) in a single asset type. The risk is that the DoD might, for example, plan an air war with hundreds of planes but fail to provide sufficient ground forces to follow up and finish the job.

Systematic risk (non-diversifiable) cannot be eliminated by having a portfolio with many asset types. This risk affects the entire economy (or a sector of it), and is also known as market risk. This is important in evaluating economic risk when deciding which assets to include in the defense strategy. Risk has profoundly shaped how institutional portfolios are managed and has motivated the use of passive investment management techniques.

The mathematics of portfolio theory is used extensively in Financial Risk Management (Financial Risk Management, 2008) and was a theoretical precursor for today's Value-at-Risk (VaR) (2009) measures (Portfolio Theory).

PA is the art and science of allocating scarce resources to satisfy strategic objectives, or determining how to best spend limited dollars (Flynn & Field, 2006). PA also provides tools for organizing and managing a set of projects in a portfolio of projects to meet its goal (COCP, 2004). Portfolio Management begins with an enterprise-level identification and definition of market opportunities and then prioritization of those opportunities within resource constraints (GAO, 2007, p. 9). A set of projects tracked across the entire portfolio in a timely and effective manner helps senior leadership make sound decisions, data-based decisions supported by analysis of cost, schedule and performance risks. These future projects will have a National strategic impact as situations and partners change. The ability of senior leadership to adjust portfolios to meet defense needs now and in the future is critical.

PA is used by businesses to measure everything from money to performance. In the finance industry, it is used to measure the strength of a group of investments to make appropriate tradeoffs of expected return on investment and risk. Using the Markowitz Efficient Frontier (MVO, 2009), a ratio of the expected return for each asset, the standard deviation of each asset's logarithmic relative returns (measure of risk), and the correlation matrix between these assets, sets of portfolios with expected returns greater than any other with the same or lesser risk, and lesser risk than any other with the same or greater return could be identified (MVO, 2009). In the Information Technology (IT) sector, PA is used to manage priorities for resource allocation. Based on limited resources (budget), which projects should we keep while increasing profits and which are failing to perform and losing money? Whatever is being measured during the analysis, it is a key factor in the success or failure of the business. Companies commonly use Net Present Value (NPV) analysis, which can show, in today's dollars, the relative cash flow of various alternatives over a long period of time (GAO, 2007, p. 15).

In general, successful companies take a disciplined approach to prioritizing needs and initiating a balanced mix of executable development programs (GAO, 2007, p. 7).

They begin with an enterprise level approach to identifying market opportunities and then prioritize them based on strategic goals, resources available, and risk. The market opportunities with the greatest potential to succeed are included in the portfolio.

IBM focuses on what it calls “industry integrated solutions”, which are portfolios structured around customers’ and buyers’ behaviors and needs and not on specific product offerings. IBM looks at the customers’ needs and the market segments that might provide for new opportunities. The “Strike Zone” is the core business for IBM. They then look at the “traditional” opportunities where current customers might be attracted to an existing business which might be enhanced. Then they consider “pushing the envelope” opportunities where they might attract new customers or create a new business. On the very outside would be the “white space opportunity” or the most risky business. This is where IBM might develop something new to the industry—based on new customers’ wants or needs. Based on available resources and potential profitability, a balanced portfolio across all segments is obtained (GAO, 2007, p. 10).

Motorola targets market segments at the enterprise level to ensure a balanced mix of projects and resources is maintained. Their Government and Enterprise Mobility Solutions business unit uses a 70-20-10 formula where 70% of the projects and resources are for the core business, 20% in new markets with existing products, and 10% for discovering new markets and products (GAO, 2007, p. 11).

So why is PA important today? The Clinger-Cohen Act of 1996 mandates its use for all federal agencies. The GAOs “Assessing Risk and Returns: A Guide for Evaluating Federal Agencies’ IT Investment Decision-Making,” Version 1, (Government Accountability Office, February 1997, GAO/AIMD-10.1.13) requires that IT investments apply Return on Investment (ROI) measures. DoD Directive 8115.01 (Department of Defense Directive, 2005, DODD 8115.01), issued October 2005, mandates the use of performance metrics based on outputs, with ROI analysis required for all current and planned IT investments. DoD Directive 8115.02 (Department of Defense Instruction, 2006, DODI 8115.02) implements policy and assigns responsibilities for the management of DoD IT investments as portfolios within the DoD Enterprise, where they defined a portfolio to include outcome performance measures and an expected ROI. The DoD Risk

Management Guidance Acquisition guide book requires that alternatives to the traditional cost estimation be considered because legacy cost models tend not to adequately address costs associated with information systems or the risks associated with them (Mun & Housel, 2006, p. 1). The CJCSI 8410.01, (Chairman of the Joint Chiefs of Staff Instruction, 2007, CJSC 8410.01), establishes policies and procedures for the War fighting Mission Area Information Technology Portfolio Management and net-centric data sharing processes.

Over the next several years, DoD plans to invest $1.4 trillion in major weapons system programs. Continued failure to deliver weapons systems on time and within budget not only delays providing critical capabilities to the war fighter, but results in less funding for other DoD and federal needs (GAO, 2007, p. 1). With this level of spending and an upcoming reduction in DoD obligation, it is important for the DoD to spend its money as efficiently as possible. This can only be accomplished by better evaluating the programs/systems for risk before they start being funded to truly ascertain their overall value toward meeting the strategic goals of the U.S. These programs contain considerable risks in the form of cost overruns, schedule delays and performance failures.

So, what is the DoD currently doing? The DoD is using individual program managers to manage specific programs/systems, without regard to the overall strategic goal of the U.S. Each program is its own entity, with little or no interaction with other programs and program managers are not held responsible for minimizing the risks associated with their particular programs. The DoD’s service-centric structure and fragmented decision-making processes are at odds with the integrated, portfolio management approach used by successful commercial companies to make enterprise-level investment decisions (GAO, 2007, p. 18).

In 2004, the Defense Finance and Accounting Service (DFAS) implemented portfolio management in an effort to help prioritize initiatives and more closely link budget to agency strategy, while answering a presidential call for improving financial management. In doing this, they developed an approach which not only governs technology investments but includes all high-value initiatives ($250,000 or more). As a decision-making tool, Portfolio Management requires essential data about all initiatives to be entered into a central database and requires those initiatives to be scored against basic criteria and risk (decision analysis). Portfolio Management treats existing and new initiatives as assets to be managed instead of costs. The process is dynamic and iterative so that the Portfolio reflects changing agency goals and priorities. The key to assessing portfolio effectiveness is measuring the right things. Because of the importance of performance measures in completing the portfolio requirements, it is crucial for DFAS to agree on the appropriate measures early in the Portfolio Management process. Each initiative receives a weighted score on three dimensions: Mission, Financial and Benefits, and Risk (Hubbard, 2004).

Using the Joint Capabilities Integration Development System (JCIDS), needs are identified, technologies are evaluated, milestone decisions are planned out and then program execution begins. The JCIDS process emphasizes early attention to the fiscal implications of newly identified needs, including the capability to divest the Department of lower priority or redundant capabilities. Despite these provisions, assessments of war fighting needs continue to be driven by the services and to be based on investment decision-making processes that do not function together to ensure that DoD pursues needs that its resources can support (GAO, 2007, p. 19). Another issue is that, unlike commercial enterprises which can make program decisions, the services and program managers can not. The DoD has functional capability boards that oversee each of eight functional areas. The boards lack the authority to allocate resources and to make or enforce decisions to divest their capability area of existing programs to pay for new ones (GAO, 2007, p. 21).

B. PROJECT BACKGROUND

According to former Secretary of Defense (SECDEF), Donald Rumsfeld, “What you measure, improves.” In this regard, the DoD is adept at measuring the cost and the value of a specific program to fulfill a specified mission. Trade-off studies are conducted and analyses of alternatives are performed. Sometimes, gap analyses are performed. But are such comparisons made program to program? Are funding decisions made with an emphasis on leadership strategy and national objectives? Portfolio analysis is a promising method to improve DoD business practices by analyzing a portfolio of systems as a whole, rather than analyzing individual acquisition programs or cost. While the above statement is in fact true, PA can be utilized as low as the command level to evaluate programs and projects using real options, whether current or future, used or not, at no current cost to the command. These options can then be sent to the senior commands for further evaluation and placement into higher level options, all the way to the department/service level. Once at the department/service level, the decision makers have a better tool to evaluate these options against the national strategic plans in order to make a better-informed decision.

In the U.S. Military context, risk analysis, real options analysis, and portfolio optimization techniques are enablers of a new way of approaching the problems of estimating ROI and the risk-value of various strategic real options (Mun & Housel, 2006, p. 1). This analysis can be performed by running various risk modeling programs including, Monte Carlo Simulations, Stochastic Forecasting, Real Options Analysis (ROA), and Portfolio Optimization using Knowledge Value Added (KVA). These methodologies help in making the best possible decisions, allocating budgets, predicting outcomes, creating portfolios with the highest strategic value and ROI, and so forth, where the conditions surrounding these decisions are risky or uncertain (Mun & Housel 2006, p. 2; Davis, 2003).

What are these modeling programs? Monte Carlo methods are a class of computational algorithms that rely on repeated random sampling to compute their results. Monte Carlo methods are often used when simulating physical and mathematical systems. Because of their reliance on repeated computation and random or pseudo-random numbers, Monte Carlo methods are most suited to calculation by a computer. Monte Carlo methods are useful for modeling phenomena with significant uncertainty in inputs, such as the calculation of risk in business. In Stochastic Forecasting, the objective is to minimize a given cost function that depends on a large number of discrete or continuous variables. ROA applies financial options valuation techniques to real physical assets and capital budgeting decisions (Campbell & Harvey, 2002). ROA itself is the right, but not the obligation, to undertake some business decision; typically the option to make, or abandon, a capital investment (Fintor, 2009). PA provides decision makers with an efficient set of portfolios, based on minimizing risk subject to a particular return

(Walls, 2004). Risk modeling refers to the use of formal econometric techniques to determine the aggregate risk in a financial portfolio. Risk modeling is one of many subtasks within the broader area of financial modeling. Risk modeling uses a variety of techniques including market risk, VaR, Historical Simulation, or Extreme Value Theory in order to analyze a portfolio and make forecasts of the likely losses that would be incurred for a variety of risks. Such risks are typically grouped into credit risk, liquidity risk, interest rate risk, and operational risk categories (Fintor, 2009).

As part of the project background, we must include a short discussion about risk. So what is risk? Risk is any uncertainty that affects a system in an unknown fashion and its ramifications are unknown, but it brings great fluctuation in the value and outcome. Risk has a time horizon, meaning that uncertainty evolves over time, which affects measurable future outcomes and scenarios with respect to a benchmark (Mun & Housel, 2006, p. 33). The DoD does not just budget for one year at a time. There are annual fully funded programs and multiyear funded programs. There are programs that have annual appropriations, bi-annual appropriations, and five-year appropriations. The question then is, how does the DoD plan for these out year budgets while accounting for the risk of program failure, increased cost, delays in scheduled deliveries, changes in strategic options and goals, or even the inadequacy of technological maturity? Every four years we elect a new administration, which creates its own foreign policy and strategic objectives. As these objectives change, so must the analysis of DoD's portfolios and their ability to satisfy our national strategic objectives. One would hope that the budgeting process was one in which the DoD entered with its eyes wide open and with a full understanding of the risks involved. So what could the DoD be doing to minimize risk? First, instead of looking at the short term and making decisions based on current ROI or cost, they should look toward the long term investment risk-return ratio, total strategic value, to include returns, cost, strategic options, (options available now or later, whether taken or not), as well as risk (Mun & Housel, 2006) and reduction of program duplication across services.

The Pentagon is in the midst of making investment decisions using so-called "capability groups" across the entire military, as opposed to managing them on a service-specific, program-specific manner. Enhancing the "portfolio management" initiative is one of the items on SECDEF England's list of goals he would like to accomplish by the end of this year. England launched the initiative in 2006 to group closely related military systems from all Services and DoD Agencies and manage them in groups. A similar mechanism has been established for Command and Control (C2) systems. The goal is to keep the military services from pursuing redundant and pricey platforms. In his February 7th memo, England directed that four capability groups, tested during the construction of the Pentagon's 2009 budget blueprint, be made permanent. Under those now-official groups, military programs from across the DoD will be grouped into these four categories to help with investment decisions: C2; Battle Space Awareness; Network-Centric Warfare (NCW); and Logistics (Bennett, 2008).

Hopefully, the DoD master national strategy will help to guide investment decisions based on the entire national strategy and across all services rather than on the needs or wants of a single service, using capability requirements. This has been addressed as recently as September, 2008 with the release of DoD Directive (DODD 7045.20, 2008), Capability Portfolio Management. The nine capability areas outlined in the DODD are: C2, Battle Space Awareness, NCW, Logistics, Building Partnerships, Protection, Force Support, Force Application, and Corporate Management and Support. The latter five are in the interim phase through Fiscal Year (FY) 2010 Program Objective Memorandum. The main policy point is stated as such: The DoD shall use capability portfolio management to advise the Deputy Secretary of Defense and the Heads of the DoD Components on how to optimize capability investments across the defense enterprise (both materiel and non-materiel) and minimize risk in meeting the Department's capability needs in support of strategy (DODD 7045.20, 2008).

We have talked about both PA and portfolio management a great deal up to this point. To clarify, this paper focuses on PA, but in doing so, we must also discuss portfolio management. There are similarities, such that in both portfolio (decision) analysis and portfolio management one must analyze and practice risk management. PA, using the Markowitz Efficient Frontier (MVO, 2009) optimization approach, provides decision makers with an efficient set of portfolios based on minimizing risk subject to a particular return.

Portfolio Management, on the other hand, provides guidance as to what level of risk-taking is appropriate. PA alone does not provide managerial guidance about which efficient portfolio is best for the organization. Combining PA and portfolio management can improve the overall decision process, and could ultimately improve organizational performance (Walls, 2004). This paper focuses on the first phase, Analysis, as depicted in Figure 1 below.

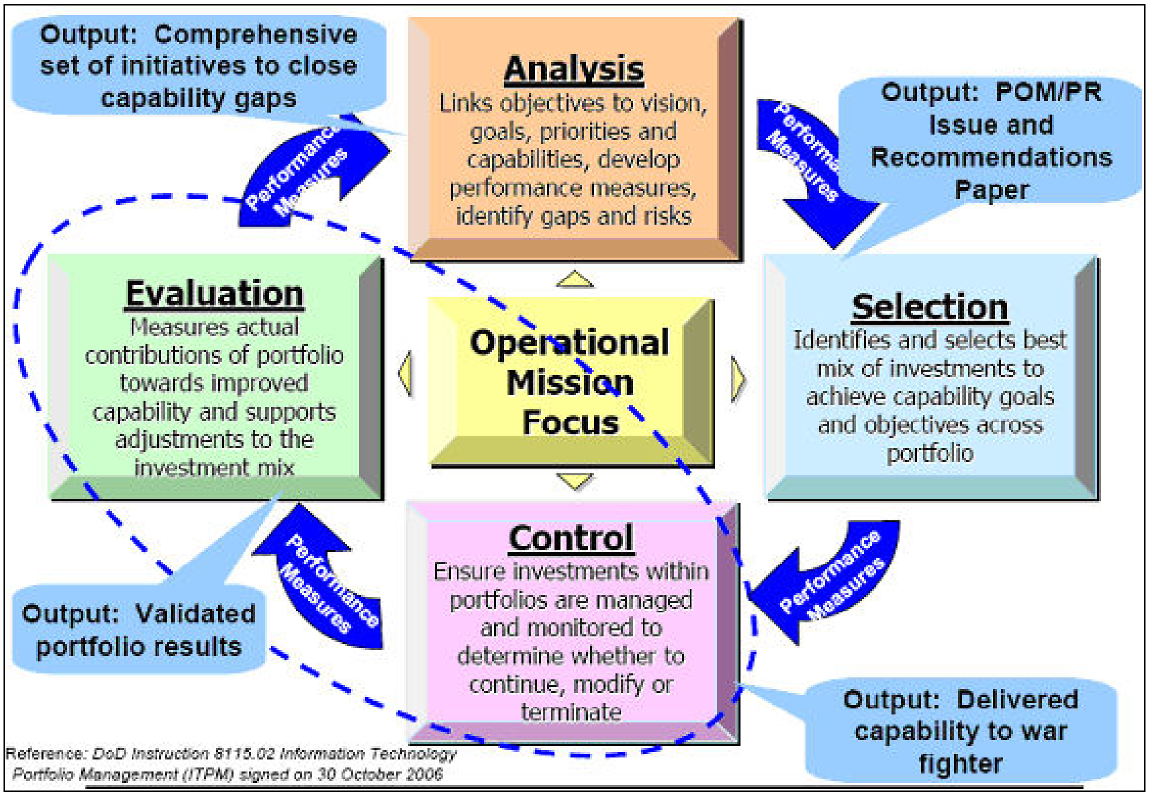


Figure 1. Analysis Phase of Portfolio Management Process

When the Honorable Richard Greco, Jr., Assistant Secretary of the Navy (Financial Management and Comptroller), entered his position in late 2004, he was asked by the Vice Chief of Naval Operations to consider devising methods that could be used to analyze programs and better inform resource decision making early in the Planning, Programming, Budgeting and Execution process. This request was the beginning of an effort to analyze common and best practices in government and in the private sector and then to use and augment those techniques in a Department of the Navy (DoN) construct.

A Mine Countermeasures (MCM) PA pilot was established and fifteen Subject Matter Experts (SMEs) were allowed to score forty different systems and six platforms using a model similar to that used at U.S. Special Operations Command, the Strategy-to-Task Model, which is an exemplary DoD model. In the MCM pilot, common criteria were established based on the strategic goals of the organization. In scoring capabilities and risks of MCM systems, a logical, rigorous, strategy-to-tasks approach is used, designed to link individual assets such as ship's sonar, and influence-sweep sleds to broad-based, macro national security objectives. By employing this approach, current and proposed systems are evaluated in terms of their contribution to the goals and priorities set.

C. PROJECT METHODOLOGY

1. Problem Identification

Dr. Flynn has already identified common problems with regard to existing DoD models and portfolio management techniques. Most existing DoD models fall short. For example, Analysis of Alternatives and campaign analyses are not PA. Other models and processes consider only a subset of tasks, costs, and capabilities and do not take a holistic view of the portfolio. Other common problems include (Flynn & Field, 2006):

a. Portfolios do not reflect national strategy,
b. Poor overall quality with regard to project selection,
c. Lack of focus on the right projects; resources are wasted on the wrong projects, and
d. Multi-year funding designed to save money and improve the defense industrial base not being appropriately utilized.

Multi-year contracts are expected to achieve lower unit costs compared to annual contracts, through one or more of the following sources:

a. Purchase of parts and materials in Economic Order Quantities,
b. Improved production processes and efficiencies,
c. Better utilized industrial facilities,

d. Limited engineering changes due to design stability during the multiyear period, and
e. Cost avoidance by reducing the burden of placing and administering annual contracts.

The use of multi-year contracts does not come without risks; such as increased costs to the government, should the multi-year contract be changed or canceled, and decreased annual budget flexibility for the program and across the DoD’s portfolio of weapon systems (GAO, 2008, p. 5).

Part of our methodology will be to use the integrated risk analysis framework as outlined by Dr. Mun. The framework consists of eight distinct phases of a successful and comprehensive risk analysis implementation. The eight phases (Mun & Housel, 2006, pp. 22, 23) are:

1. Qualitative Management Screening
2. Time-series and Regression Forecasting
3. Base Cost NPV Analysis
4. Monte Carlo Simulation
5. Real Options Problem Framing
6. Real Options Modeling and Analysis
7. Portfolio and Resource Optimization
8. Reporting and Updating Analysis

Using this framework, we will develop a sample scenario which will approximate a basic DoD program, with options over a set time period. Using this scenario we will test several COTS programs to evaluate which product, in fact, provides the best analysis for use in the DoD based on the eight phases of the risk analysis framework.

2. Systems Engineering

Systems Engineering is responsible for overseeing the COTS/Government Off-the- Shelf (GOTS) analysis and selection process and developing appropriate criteria for assessing and evaluating the applicability and fit of existing components pertaining to the current development effort. Gathering and assessment of COTS/GOTS (C/G) product data may be performed by specific domain engineers or SMEs. There are new methodologies, which are helping to make the best possible decisions, allocate budgets, predict outcomes, create portfolios with the highest strategic value and ROI, and so forth, where the conditions surrounding these decisions are risky or uncertain (Mun & Housel, 2006, p. 2). For this research paper, a Systems Engineering effort has been conducted using a COTS life cycle model. The COTS life cycle model produces a system primarily out of one or more available COTS products. This means that the system functionality being developed, the system performance and the operational characteristics are primarily driven by what is commercially available. Requirements and system objectives are developed to understand the functionality and performance characteristics, and are then used as requirements to select a set of COTS products that provide most of the system functionality and desired performance. Instead of relying purely on immediate ROI or cost, a project strategy, process innovation, or new technology, should be evaluated based on its total strategic value, including returns, cost, and strategic options, as well as risks (Mun & Housel, 2006, p. 2).

3. COTS Integration Life Cycle

The goal of the COTS Integration model is to build an end product that is primarily an integration of available COTS products. The outcome of this model is a product solution that will meet customer/user requirements. COTS products are identified and analyzed for use in the proposed solution. A main advantage of using the COTS Integration model is the speed at which a product can typically be rolled out to the customer/user. Also, by incorporating COTS products for certain functions, there is usually a high level of confidence that the end product will work according to expectations of the COTS products. However, not all requirements may be satisfied by the solution and it is important that the customer/user accepts the limitations that the COTS product(s) may impose. The customer may need to trade specific functionality or at least be able to be flexible with regard to the solution. For example, a COTS product may dictate a change to a customer process flow, or may require the customer to provide needed functionality from another source. The COTS Integration life cycle promotes a set of activities that supports a customer's need for implementing an 80/20 rule-type project (i.e., to produce a system with 80% of the desired functionality with 20% of the cost and/or schedule).

To begin the analysis, capability requirements are developed in the form of product requirements. Next, available COTS products are identified and analyzed for use in the proposed end product. The capability requirements are then mapped to product features. While the process is simple, the spectrum of COTS PA products is broad, and the requirements are specific to DoD. The analysis needs to encompass the multi-dimensional aspects of product feature comparison and total-cost-of ownership. The work that Dr. Flynn has done in identifying attributes of PA has been used as requirements for PA product research and comparative analysis. Product literature, demonstrations, downloadable evaluations, vendor interviews, and objective product reviews will be used to plot each PA solution's capabilities against the requirements provided by Dr. Flynn (Flynn & Field, 2006).

4. COTS Analysis and Selection

The C/G analysis and selection System Engineering and Integration process component considers a wide range of existing and available COTS and GOTS system products (ranging from individual hardware components or software algorithms or modules to large system components) for use in current system development. This process is based on the technical assumption that certain parts of large systems can be effectively and efficiently assembled through use of existing components and this use can potentially reduce development costs, enable rapid assembly and integration of systems, and reduce the maintenance costs associated with the support and future upgrade of the overall system. There are typically two major activities for this process:

a. Analysis of current operational and support requirements, and
b. Availability of C/G elements to meet requirements and selection of the appropriate C/G products to incorporate into the current system development effort

5. Appropriate Data

According to Dr. Flynn, the government needs to implement PA to quantify and justify programming and budget decisions during the Planning, Programming, Budget, and Execution process (Flynn & Field, 2006). He asserts that, when armed with this analysis, senior leadership can alter projects, drop projects, or increase projects based on current threats and proposed future needs. Establishing a portfolio of projects that can be altered, based on the current world situation, best value for the government dollar and new technology, is a best business practice that other industries are already utilizing. Dr. Flynn further asserts that the private sector uses a common metric (i.e., dollars) to determine value.

There is no commonly defined metric for value across DoD programs. As a result, military value is extremely difficult to determine and must be subjective. Dr. Flynn has provided information on the criteria and data that is required to conduct PA for the purpose of evaluating programs comparatively. He proposes replacing the Expected Commercial Value model (used in commercial contexts) with an EMV. The National Security Strategy of March 2005 identifies four strategic objectives and eight required operational capabilities of U.S. military forces. The EMV, in one of many constructs, is a function of the strategic importance of a project, the degree to which the capability is desired, as well as probabilities of technical and operational success. It is important to note that the variable for Strategic Importance is influenced directly by strategic objectives; similarly, the degree of capability desired is influenced by key operational capabilities.

6. Life Cycle Activities

Engineering activities in the COTS Integration life cycle begin primarily with an iterative interaction between the Requirements and Concept Development, Analysis and Initial Design, Architecture Definition and C/G Analysis and Selection components. Within Requirements and Concept Development a set of initial system objectives are elicited and compiled into a product vision or feature list. This information is then used to identify and collect information about existing products that could satisfy customer needs. Trade Studies represent a key technical management component that supports the life cycle activities. Among the greatest risks in a C/G-type project are the actual performance of the selected products and the performance of C/G products that may be integrated and interfaced in ways that were previously not considered. Trade Studies, conducted within the Decision Analysis and Resolution component, using a set of potential C/G products executing in realistic scenarios, can significantly reduce this risk to the project.

7. Design, Integration and Evaluation Activities

Once the prospective COTS products have been identified, Detailed Design and Verification activities can commence. Detailed Design is focused on the system capabilities that are needed to enable the selected COTS products to interact with each other and/or the user (e.g., glue components). Therefore, it should represent a very minimal activity. It is conceivable that Detailed Design may not even be needed (e.g., a single COTS system is selected to provide the entire functionality). Early Verification activities focus on demonstrating that the chosen C/G products actually perform as anticipated on the project and support the required interfaces. Verification of the components can be thought of as "unit tests" for the components that are going to be integrated into the delivered system.

8. System Engineering Activity Descriptions

a. Perform Initial Analysis of C/G Elements

Our research team will perform initial analysis of the C/G elements, including identifying the screening criteria for evaluation of GOTS/COTS candidates and evaluating the properties of candidate C/G components. Such properties include component functionality (what services are provided) and other aspects of a component's interfaces (e.g., standards implemented, operational environment). These properties also include quality and supportability aspects of the components that may be more difficult to isolate and quantify than component functional and performance aspects. Based on the screening, a short list of candidate C/G components will be identified for use in the next activity.

b. Perform Literature Review

Our research team will collect information on PA solutions to obtain case studies, and industry best practices. The following sources will be used:

- DoD components and defense firms
- Journal articles
- Academic and Wall Street SMEs
- Periodicals and magazines which conduct product comparisons
- Other industries utilizing PA

c. Select Appropriate C/G Elements for Inclusion in Current System Development

Our research team will determine the "fitness for use" of existing C/G components that are candidates for application in the new system development effort. We will then determine which available C/G components represent a "best fit" for the current development effort. It is also reasonable to discover "non-technical" component properties, such as the vendor's market share, past business performance, and process maturity of the developing organization. The selection process may also extend to include qualification of the development process used to create and maintain candidate C/G products. The determination on use of existing C/G products may be dictated by the acquirer or another appropriate stakeholder. Thus, this process may actually be executed in advance of completion of the Requirements and Concept Development process since the outcome of the C/G analysis and selection may impact the development and definition of system requirements.

II. SYSTEM ENGINEERING (SE)

A. REQUIREMENTS

1. Objectives

SE begins with the capture of requirements. For this research project, several sources were used to establish requirements. In understanding the requirements provided from different organizations, it is necessary to understand how each organization defines PA. The Project Management Institute defines:

Portfolio as "A collection of projects and programs and other work that are grouped together to facilitate effective management of that work to meet strategic business objectives. The projects or programs of the portfolio may not necessarily be interdependent or directly related."

Portfolio Management (PfM) as "The centralized management of one or more portfolios, which includes identifying, prioritizing, authorizing, managing, and controlling projects, programs and other related work to achieve specific strategic business objectives."

PfM, in the context of this research paper, views each program investment from an enterprise level as contributing to the collective whole, rather than an independent and unrelated program investment. With this enterprise perspective, Portfolio Managers can effectively:

a. Identify and prioritize opportunities and
b. Apply available resources to potential products to select the best mix of products to exploit the highest-priority and/or most promising—opportunities (GAO, 2007)

This type of approach depends on strong enterprise governance with committed leadership; it also depends on information tools which provide the ability to visualize complex data relationships in a comprehensible manner.

As depicted in Figure 2, a PfM approach begins with an enterprise-level framework and definition of market opportunities and then the prioritization of those opportunities within resource constraints. At each review gate, programs are assessed against available resources, established criteria, competing programs, and the goals and objectives of the DoD as a whole. As alternatives pass through each review gate, the number is expected to decrease, until only those alternatives with the greatest potential to succeed make it into the product portfolio (GAO, 2007).

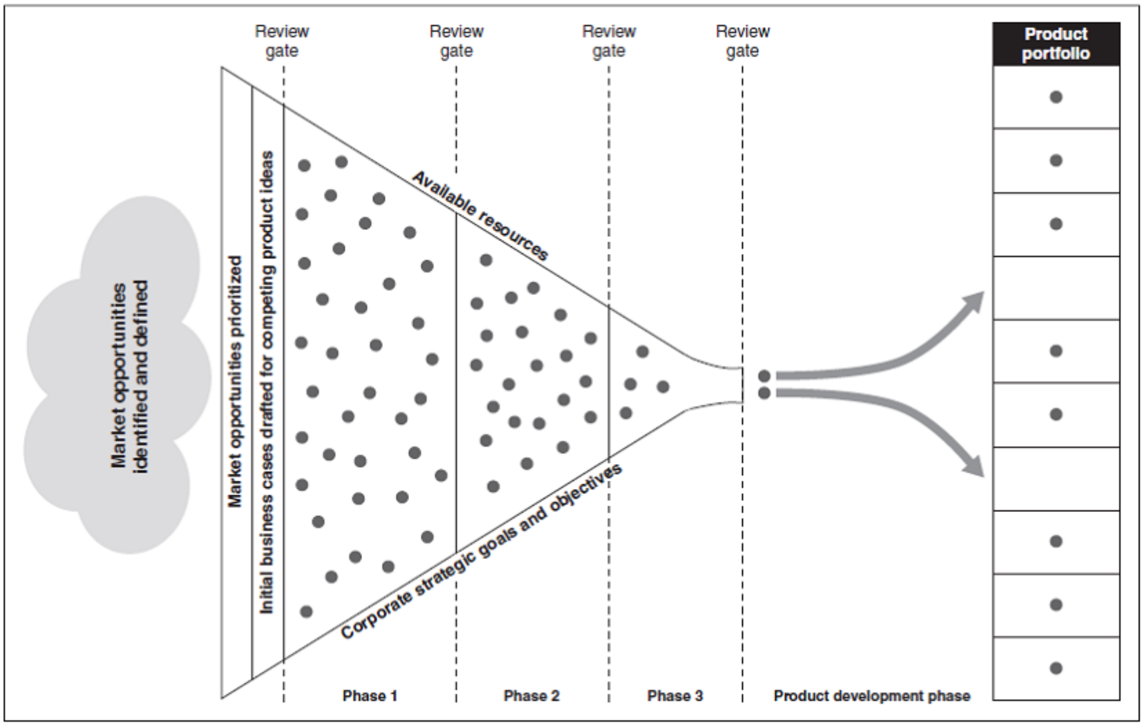


Figure 2. PfM Approach to Product Investments (From GAO, 2007)

In support of the framework identified as a best practice by the GAO (GAO, 2007), a fundamental premise of this paper is the need to identify COTS systems that can provide the capabilities identified in the Requirements section.

This project analyzes applicable PA tools, systems and underlying methodologies in terms of relevancy to identification of viable requirements and technical alternatives. As depicted in Figure 3, the PA activities include:

- Identifying and Maintaining the Baseline
  - Collecting data
  - Grouping Investments into Capability Areas

- Identifying Gaps
    - o Using the formula GAPS = OBJECTIVES-BASELINE
- Identifying Initiatives to Close Gaps

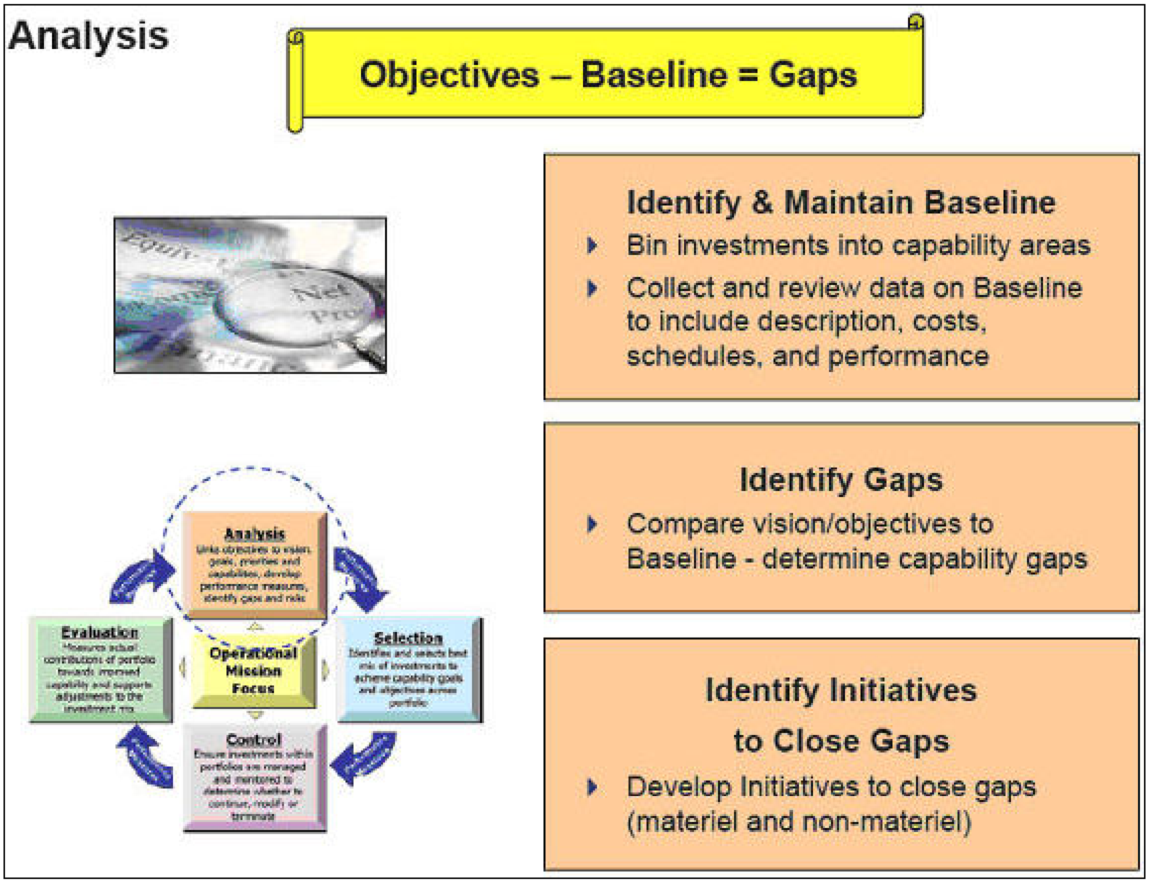


Figure 3. Portfolio Analysis (PA) Activities (From Mean-Variance Optimization, 2009)

2. Scope

This research project encompasses PA pertaining to the DoD, as identified in the requirements provided, both explicit and derived. Some interpretation of requirements is needed as requirements are decomposed into functional capabilities. These interpretations, in terms of this paper, have not been presented to, nor vetted with the authors and agencies that provided the top-level requirements. The research scope fully explores the applicability of PA systems, vis-à-vis the requirements, using a System Engineering approach.

This report focuses on identifying current COTS PA systems, operational constraints of current systems, and general recommendations for system implementations. The technology evaluated includes PA software, computers and related technology. The approach includes gathering the information needed (requirements, best practices) to conduct COTS product evaluations.

3. Identified Needs and Best Practices

This section begins to address the research questions in terms of performance, functional requirements, and system requirements. As outlined in the Project Methodology, a Literature Review was conducted to examine the current PA landscape from a requirements perspective. The key requirements were drawn from the sources shown in Appendix B.

4. Capability Requirements

Table 1 depicts the Capability Portfolio Analysis as a function of Cost, Schedule, and Performance.

Table 1. Capability Portfolio Analysis as a Function of Cost, Schedule and Performance

Portfolio Item	Capability Development	Capability Equipment Components	Capability Interfaces	Capability Installation	Capability Life-Cycle Logistics
Notional Baseline	Current Available Capability	Current Component Availability	Current System or Equipment Interoperability	Historical Installation Cost and Schedule for similar Capability	Historical administration, training, parts kits, publications, design changes, etc. for similar Capability
Cost as a Function of Increase, Decrease, or Change to any Portion of the Program	Changes to application of the Capability (all changes equate to cost increase and schedule impact +/-)	Cost will be constant or an increase for systems if any components, software, etc. are changed. Cost increase may be offset by reduction in components. May also affect	Cost may be same as notional or will be + for integration with any new components. Equates to information distribution, whether internal to the equipment or as external	Cost may be same as notional cost, an increase, or a decrease depending upon a number of factors, including location, difficulty of installation or	Only historical baseline costs will remain the same. Any change, regardless of increase or decrease in capability will equate to a positive cost over baseline.

Portfolio Item	Capability Development	Capability Equipment Components	Capability Interfaces	Capability Installation	Capability Life-Cycle Logistics
		schedule and/or performance.	interfaces.	delivery, and differentials to security, environment and others.	
Schedule as a Function of Weighted Tasks and Earned Value Metrics	Any changes to baseline capability will have an impact to schedule, but established delivery date must be the goal.	Whether COTS or GOTS based, component availability that satisfies the capability affect schedule +/-.	Level of integration of components of the capability affects tasking and Earned Value within the schedule +/-.	Degree of difficulty, location, etc. will affect schedule +/-.	Procurement and Documentation approval may or may not affect overall schedule +/-.
Performance as a Function of Technology Readiness Levels (TRL) (1-9) and Manufacturing Readiness Levels (MRL) (1-10)	Assume legacy capability as constant (TRL 9 and MRL 10). Any change to capability will have commensurate impact on Technology or Manufacturing Readiness either +/-.	Legacy components, whether COTS or GOTS are TRL/MRL 9/10 respectively. Current state of portfolio components will impact cost, schedule, and performance. Higher TRL/MRL the less impact on cost and schedule, but may impact life cycle logistics, interfaces, and installation significantly.	COTS vs. GOTS are significant factors for interfacing with other systems. Even with high TRL/MRL degree of difficulty may be deciding factor. COTS may be acceptable as standalone interim solution with a migration plan for later GOTS integration.	Installation Phase assumes high MRL/TRL, but physical or electronic characteristics must be considered in performance as these may impact cost and schedule.	Affected +/- depending on degree of acquisition management interfaces required and Performance Based Logistics level of effort for life cycle sustainment.

The Cost of Capability Concept must also be considered, but may be viewed as a pre-expenditure, or constant plus a fixed fee for changes. The capability concept document is pre-portfolio selection, and assembly of capabilities as portfolios to meet the mission need should be based on this concept document. Inflation over time is a constant for any capability selection from the portfolios and is not considered a major factor in selection.

5. Functional Requirements

The Requirements Matrix, Table 2, shows the payload of the SE requirements analysis. The requirements matrix provides the foundation for analyzing the products vis-à-vis the requirements. The requirements are specified using performance characteristics which are decomposed to include functional aspects, system aspects, and identification of tests that are used to ensure the requirements are satisfied.

Table 2. Requirements Matrix

Category	Classes	Measures	Metrics	Group By	Notes
Operations	Mission Effectiveness	Speed of command	Time	Capability, Service	Fact
		System Availability	Ao	System	Fact
		Quality	Morbidity		Facts, Score
		User Defined	[numeric value]		Score
		Public Service	0/1 (Binary)		Score
		Transformational Impact	0/1 (Binary)		Score
		Situational Awareness	#of Tracks		Fact
		Interoperability	Military Standard		Score
Category	**Classes**	**Measures**	**Metrics**	**Group By**	**Notes**
Logistics	Footprint	Lay down Effects	Space, Inventory Quantity, Training	Material, Non-Material	Facts, Scores
	Acquisition Risk	Item Value	Unit Cost		Fact
	Supplier Leverage	Number of Suppliers	#Qualified Suppliers		Fact
	Total Cost of Ownership	Life cycle Cost	Complete System Costs		Fact
Category	**Classes**	**Measures**	**Metrics**	**Group By**	**Notes**
Strategic Alignment	Business Model	Organizational Fit	0/1 (Binary)	Strategies, Term (short, long)	Score
	Organizational Impact	Training	Cost		Fact
		Personnel	#People, #Man Hours		Facts
	Business Process Improvement	Scope	ROI/EMV**		Fact

Category	Classes	Measures	Metrics	Group By	Notes
Cost/Benefit	Dollar Value	Return On Investment	Cost, Payback, Payback Period	Phase (RDT&E, Production, O&S)	Fact
	EMV	Return On Investment	Cost, EMV, EMV Payback Period		Fact
Category	**Classes**	**Measures**	**Metrics**	**Group By**	**Notes**
Execution Performance	Schedule	EVM	Schedule Value	Program, Service, Phase	Fact
	Cost	EVM	Cost Value		Fact
Category	**Classes**	**Measures**	**Metrics**	**Group By**	**Notes**
Risk	Probability	Rating	1 through 5 Ratings, Percentage	Program, Service, Phase	Score
	Consequence		1 through 5 Ratings, Percentage		Score
Category	**Classes**	**Measures**	**Metrics**	**Group By**	**Notes**
Organizational Impact	Training	People Affected	Count	Program, Service, Phase	Fact
	Personnel	People Affected	Count		Fact
	Quality of Life	Surveys	Survey Metrics		Score

*** The intent of EMV is to create a single metrics equivalent to dollars in commercial PA.*

B. ANALYSIS

1. Portfolio Capability Evaluation

From the DoD acquisition perspective, capabilities to meet identified requirements that satisfy mission gaps in execution of military strategies are tied to cost, schedule, and performance. In turn then, it is logical to view portfolios in a manner that optimizes these values. Let us consider that, for an optimum identified capability requirement, the following is true, regardless of whether it is from existing legacy, evolutionary, or new development (Figure 4):

$$\sum_{concept}^{operating} Capability = \sum_{Capability-}^{Capability+} Capability$$

Capability Concept + Capability Development + Capability Equipment + Capability Interfaces + Capability Installation + Capability Logistics

Figure 4. Capabilities Equation

The summation of sub-folders in a notional capability portfolio will result in a final capability that matches the DoD mission gap requirement, is better than the requirement, or is somewhat less than the requirement, but is good enough to serve as an interim solution (a lower threshold must be established to know when a sub-folder must be discarded as not useful). In turn, each of the pieces of this notional capability (let us call them \$K or notional constant dollars for the baseline) portfolio may be further decomposed such that (Figure 5):

$$\$K_{cc} + \$K_{cd}^{+/0} + \$K_{ce}^{+/0/-\ \Delta} + \$K_{cif}^{+/+\ \Delta} + \$K_{cin}^{+/+\ \Delta} + \$K_{log}^{+/+\ \log\ \Delta}$$

Where:	$\$K_{cc}$	Is cost of capability concept
	$\$K_{cd}$	Is cost of capability development
	$\$K_{ce}$	Is cost of capability equipment/components
	$\$K_{cif}$	Is cost of capability interfaces
	$\$K_{cin}$	Is cost of capability installation
	$\$K_{log}$	Is cost lifecycle logistics for the capability including contract, initial administration, training (T), publications (P), spare parts kits (Spk), design changes (Sys) for the installation, software packages, etc.

$$T\Delta + P\Delta + Spk\Delta + Sys\Delta = \log \Delta$$

Figure 5. Summation of Capabilities

As shown above, changes (or the +/- deltas) to the notional baseline capability result in increases/decreases for cost, schedule and/or performance. At the enterprise level, then, these parameters may be used to graphically show advantages and disadvantages for various options within each of the portfolio sub-folders (we will examine the individual parameters graphically later on). This same rationale may be used for evaluating schedule and performance. When numerical values are assigned, portfolios of capabilities and their components may be evaluated to select those most favorable within cost, schedule and performance desired to meet the capability gap. Note that risk is not an issue in capability parameter selection at this point. Risk is an integral part of sub-folder or technology evaluation that may make a specific capability option within the portfolio infeasible. Risk may be evaluated at each enterprise level calculation and at each subsequent parent-child decomposition, such that risk is always a consideration throughout the selection process.

Taken in aggregate, a graphical representation of notional capability fielding may be presented, as depicted in Figure 6. Once analyses of different aspects of the portfolio (the parametric deltas from notional baseline) are examined, the graphical representation of the actual effort may be very different. Minimum and maximum arbitrary thresholds will determine whether the portfolio sub-folder capability option is able to meet cost, schedule, and performance within the timeframe desired by the tasking activity. If yes, then the portfolio sub-folder should be examined further. If no, then the capability option should be tabled for future consideration, or as a “fallback” option.

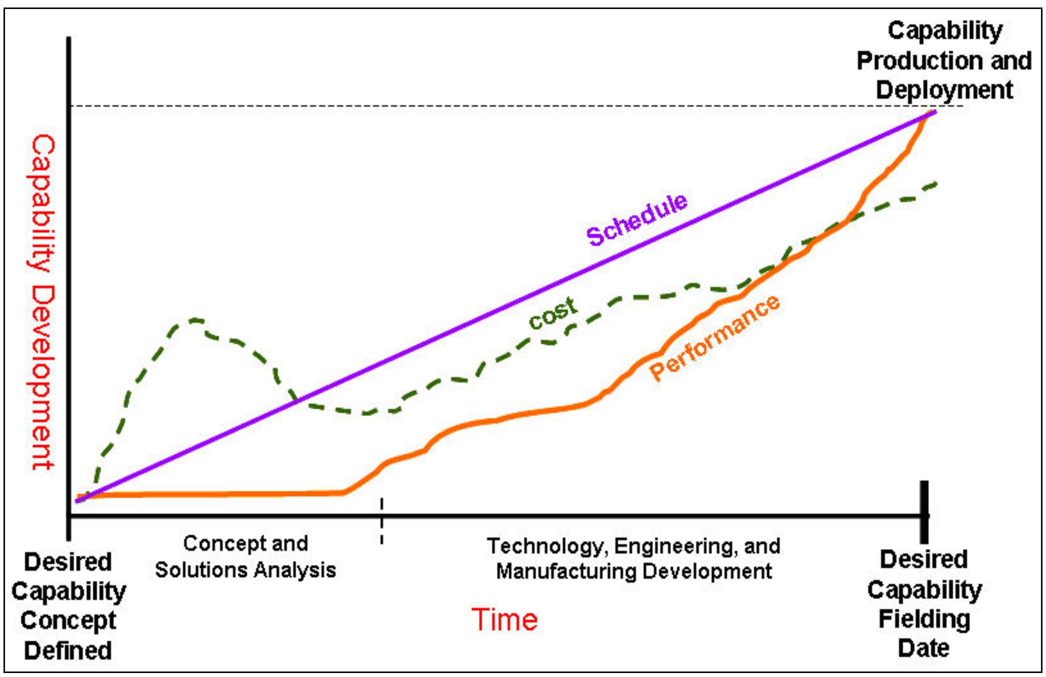


Figure 6. Graphical Representation of Notional Capability Fielding

In measuring the parametric deltas/differences for a cost valuation, consider a matrix similar to Figure 7, where notional cost is shown as a function of historical spending rates for capability development and implementation:

Total percent	2%	4%	4%	3%	3%	7%	10%	11%	11%	13%	14%	18%	100%
Concept $K	0.1%												
Capability Development	10.0%	2.1%	2.1%	0.7%	1.0%	2.9%	2.9%	2.1%	2.1%	0.7%	0.7%	0.7%	28.0%
Capability Equipment & Components	0.0%	0.7%	0.7%	0.7%	1.0%	2.8%	5.7%	6.4%	6.4%	7.9%	9.3%	10.0%	51.6%
Capability Interfaces	0.3%	0.7%	0.7%	0.7%	0.3%	0.4%	0.4%	0.7%	0.7%	2.1%	2.1%	3.0%	12.1%
Capability Installation	0.0%	0.0%	0.0%	0.7%	0.3%	0.3%	0.3%	0.7%	0.7%	0.7%	0.7%	3.0%	7.4%
Capability Lifecycle Logistics	0.9%	0.7%	0.7%	0.0%	0.3%	0.7%	0.7%	1.4%	1.4%	1.4%	0.7%	1.4%	10.3%

Figure 7. Notional Cost as a Function of Historical Spending Rates

Adding or subtracting different parameters desired from the capability portfolio sub-folders gives realistic notional thresholds for where expected costs will fall throughout the capability development and fielding, as depicted in Figure 8.

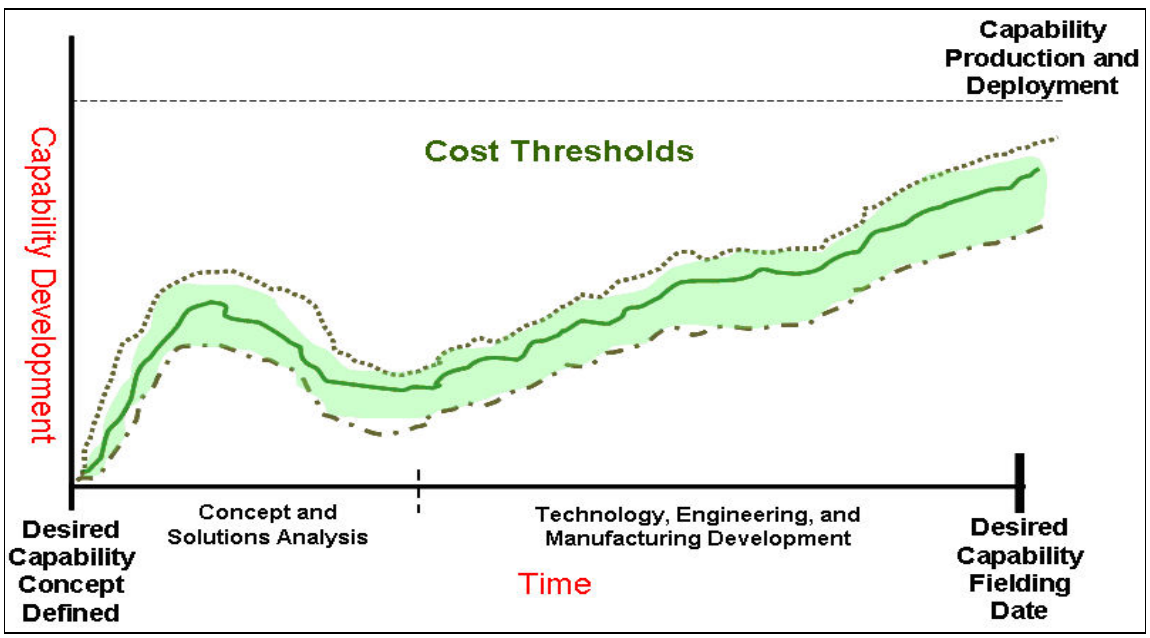


Figure 8. Realistic Notional Cost Thresholds

Evaluation of the portfolio must also consider the desired timeframe for fielding the capability. If technologies or equipment within the selected sub-folders have low probability of reaching the fielding date, they must be shelved until they are mature enough for consideration. Schedules for the selected comparison parameters must use arbitrary weighted earned values. Depending upon the capability requirement, there are several types of scheduling software products that may be used. Regardless of the scheduling tool, as long as it is consistent, a reasonable comparison may be made between portfolio sub-folders that meet notional Earned Value Management System and Integrated Defense Acquisition, Technology, and Logistics management framework milestone and alternative decision point requirements.

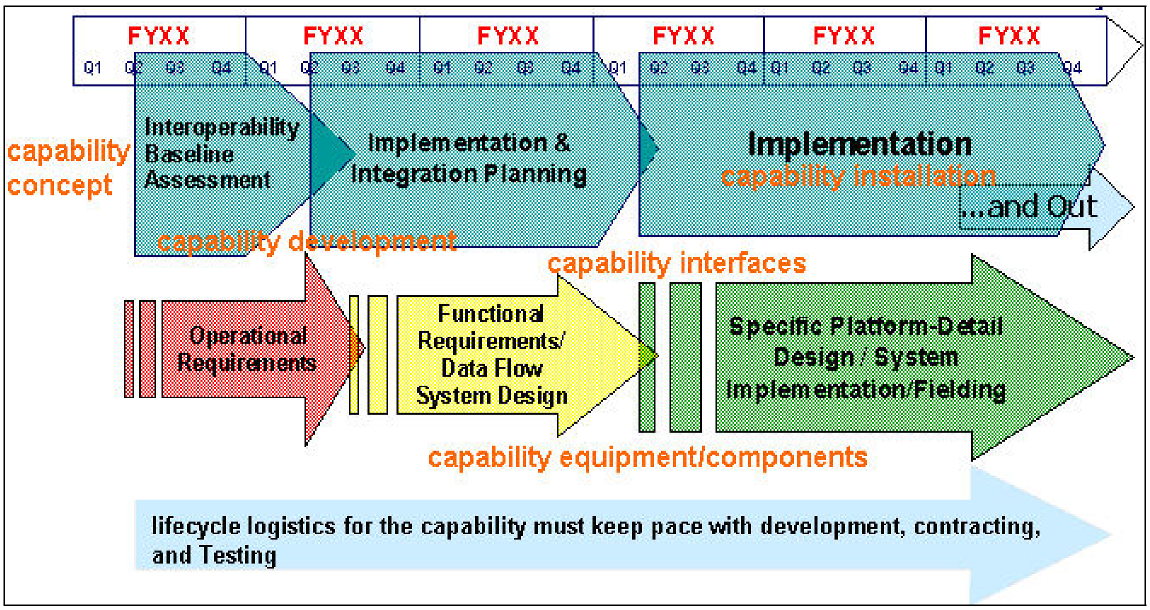


Figure 9. Simple Capability Portfolio

Very simple capability portfolios may only require something as elementary as Figure 9 above to select the best options within the sub-folders. Other complex capabilities may require in-depth project breakdown, and individual parameter comparisons within established thresholds, as shown in Figure 10. Sub-folders may also have spin-out increments to fall back on legacy technologies, should risk mitigation be insufficient to continue a specific variable.

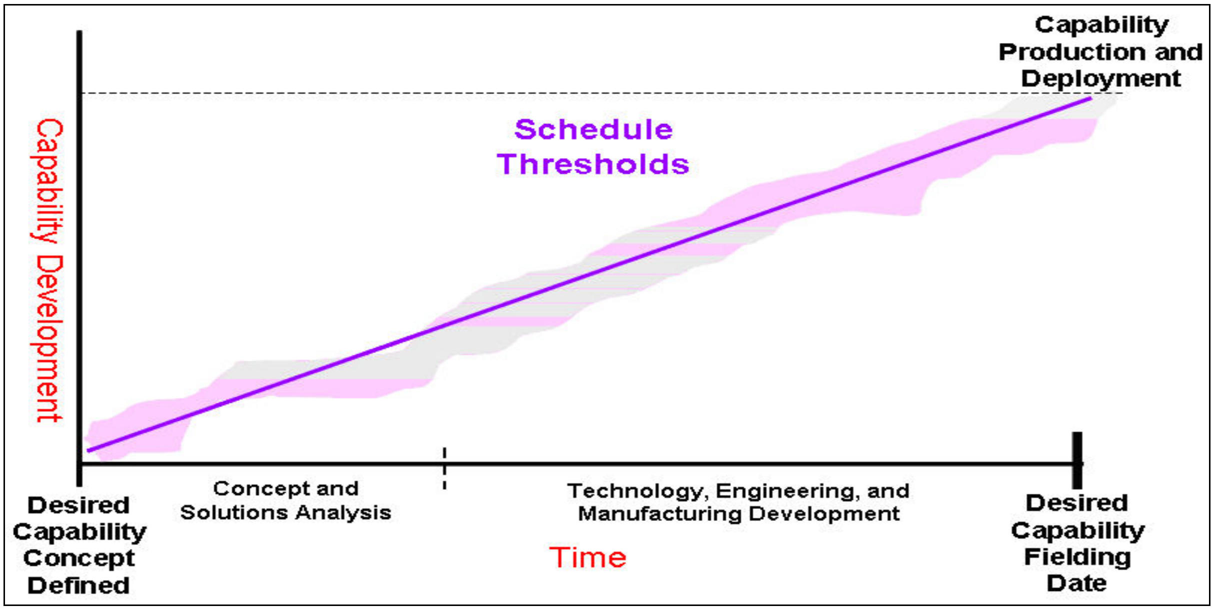


Figure 10. Complex Capability Portfolio

Evaluation of possible capability variances may be set down in simplistic spreadsheets as depicted in Figure 11 below:

SCHEDULE as a function of weighted Earned Value Tasking	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
JCIDS		**MS A**				**MS B**				**MS C**	**LRIP**	**FRP**
Capability Development				Option A			Option B					
Capability Equipment & Components				spinout option A		spinout option B						
Capability Interfaces					option A			option B				
Capability Installation												
Capability Lifecycle Logistics											PBL	

Figure 11. Evaluation of Possible Variances Depicted in Spreadsheet

When overlaid upon the notional schedule with scheduling thresholds, as shown in Figure 12, one can readily see where spinouts might be implemented across the capability fielding process. This process is especially useful in "design to price" or "turnkey" delivery of capabilities.

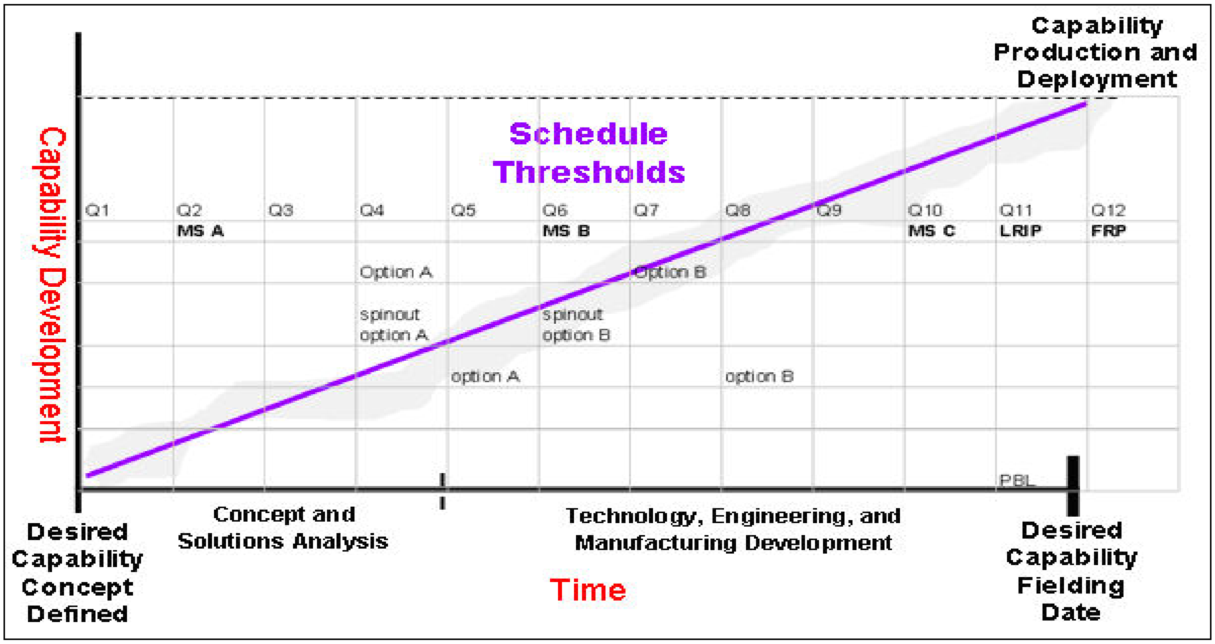


Figure 12. Notional Schedule with Scheduling Thresholds

Although the capability performance may be measured by several criteria, it may be best measured via established criteria, as set forth in a Technology Readiness Assessment and/or Manufacturing Readiness Assessment. These criteria are well-recognized throughout the DoD and other government activities. Because of the expandable nature of the requirements for each level of performance, each of the parameters for evaluating a sub-folder within the portfolio may be tailored to fit the criteria of technology and manufacturing readiness. When compared with one another, using the same criteria, selection of the most promising sub-folders for the capability can be accomplished.

Because sub-folders consider existing, evolutionary, and new developments, use of this method allows the evaluator to be able to inject capabilities into the performance versus time chart at the current level and select those that may be more mature and, therefore, have the best chance of success, all other weighted factors being near equal. The evaluator must be attuned to the pitfalls of selecting mature technologies, even though they meet a current need, which cannot evolve and remain interoperable with other capabilities in the battle space in the out years. A simplistic summary of technology and manufacturing readiness and assessment criteria is shown in Figure 13.

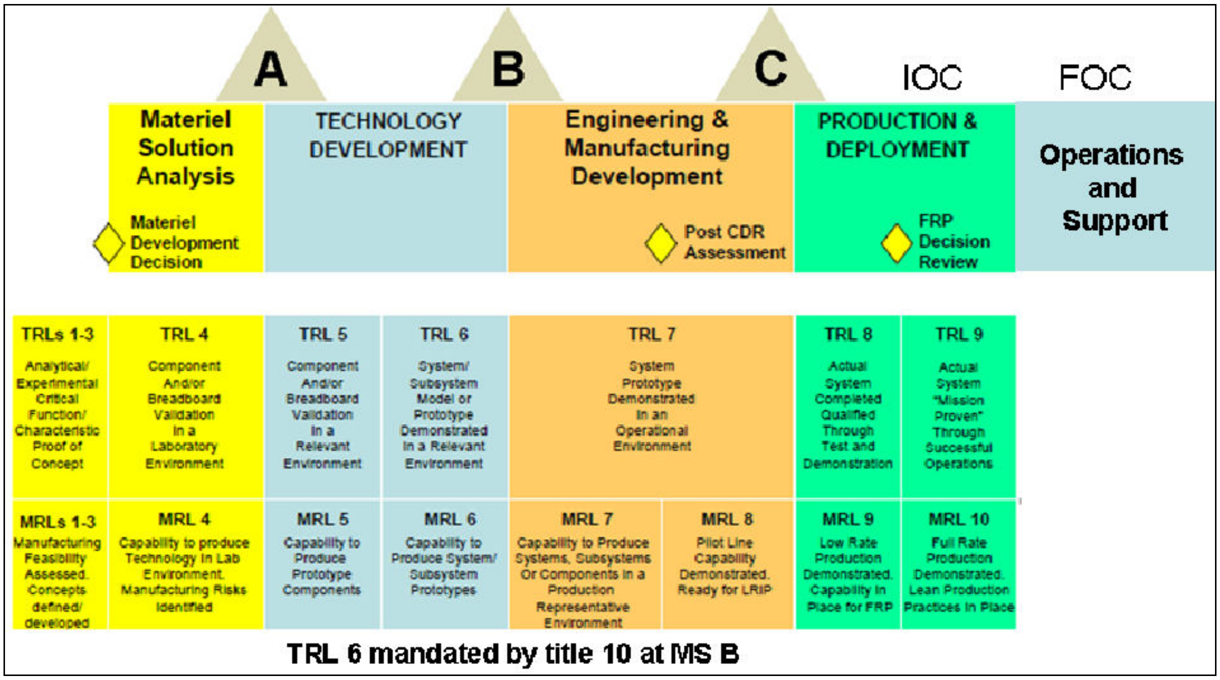


Figure 13. Summary of Technology & Manufacturing Readiness and Assessment Criteria

In evolutionary and developmental sub-folders, it must be noted that the notional performance of the capability must be at a TRL of 6 by Milestone B, as set forth in Title 10 (see Figure 14).

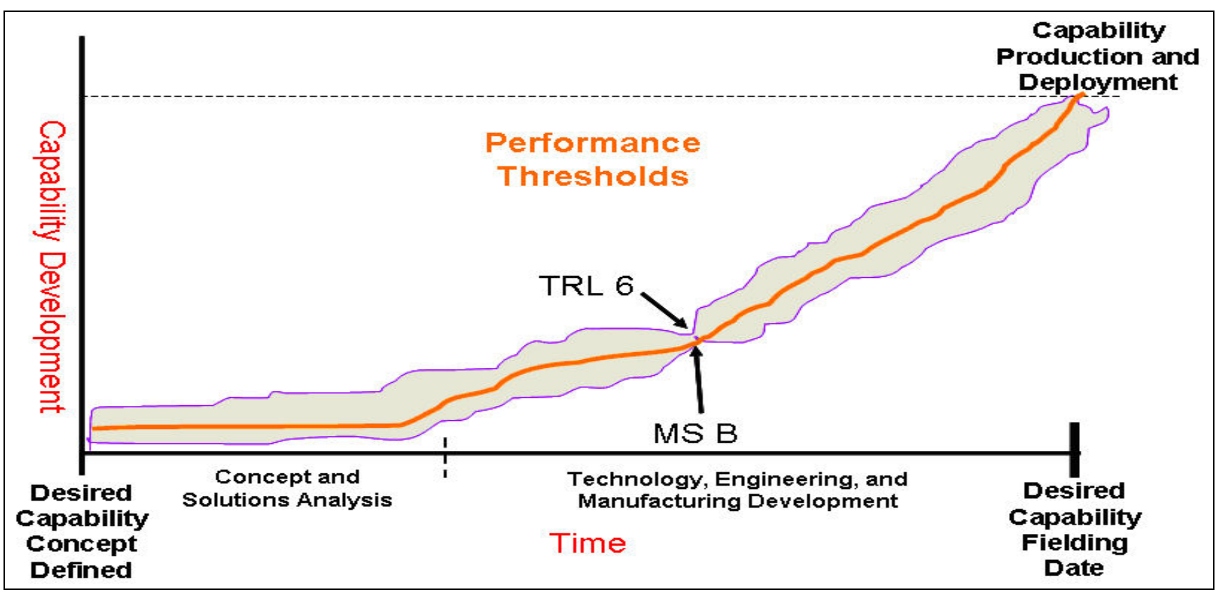


Figure 14. Capability at Technology Readiness Level 6 by Milestone B

As with scheduling, a simplistic spreadsheet, as depicted in Figure 15 below, may be completed for the notional capability and then parameters from the sub-folders overlaid to match projected performance growth over the notional timeline for the required fielding date of the capability. Again, there are many software tools, both simple and complicated, that may be used to perform this function.

PERFORMANCE as a Function of Technology & Manufacturing Readiness	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
JCIDS		**MS A**				**MS B**				**MS C**	**LRIP**	**FRP**
Capability Development						6 or >				7 or >	8 or >	9
Capability Equipment & Components						6 or >				7 or >	8 or >	9
Capability Interfaces						6 or >				7 or >	8 or >	9
Capability Installation						6 or >				7 or >	8 or >	9
Capability Lifecycle Logistics						6 or >				7 or >	8 or >	9
Notional TRL of Capability overall						6 or >				7 or >	8 or >	9
Notional MRL of Capability overall						6 or >				8 or >	9 or >	10

Figure 15. Simplistic Spreadsheet Showing Notional Performance Capability

Notional capability parameters may vary, depending upon the type of capability being fielded, and the readiness level of the parameters may vary widely, depending upon the maturity of selected sub-folders to meet the capability. However, as seen in Figure 15 above, to meet fielding criteria there are accepted readiness levels that are expected at certain proposed decision points and milestones for the capability.

2. Threat Environments (Based on the 2008 National Defense Strategy (NDS)

a. Threat Environment Current

Today's current environmental threat is: Global struggle against violent extremist ideology seeking to overturn the international state system, asymmetrical/irregular warfare.

b. Threat Environment Future

Irregular challenges, rogue states quest for nuclear weapons (Iran and North Korea), rising military power of other states (China, potentially Russia).

c. Objectives

The objectives are as follows:

- Defend the Homeland
- Win the Long War
- Promote Security
- Deter Conflict
- Win our Nation's Wars

d. Achieving the Objectives

Objectives are met by shaping the choices of key states, preventing adversaries from acquiring or using Weapons of Mass Destruction, strengthening and expanding alliances and partnerships, securing U.S. strategic access and retaining freedom of action, and integrating and unifying our efforts.

e. Risks

Since it is not possible to fund every project, ultimately choices must be made. Here risk is defined in terms of the potential for damage to national security combined with the probability of occurrence and a measurement of the consequences should the underlying risk remain unaddressed. The first risk is that partner contributions to future coalition operations will vary in size, composition, competence, and capability. Second, the risk strategy must account for four dimensions of risk:

<u>Operational Risks</u> – Those associated with the current force executing the strategy successfully within acceptable human, material, financial, and strategic costs.

<u>Future Challenges Risks</u> – Those associated with the Department's capacity to execute future missions successfully against an array of prospective future challengers.

Force Management Risks – Those associated with managing military forces fulfilling the objectives described in the NDS. The primary concern here is recruiting, retaining, training, and equipping a force and sustaining its readiness.

Institutional Risk – Those associated with the capacity of new command, management, and business practices.

3. Gartner Group's COTS PA Product Landscape

Applications for project, portfolio and resource management boost team performance and enable IT management and others to access real-time data via dashboards for prioritization and quick decision making. As clients look to better manage IT portfolios, vendors are marketing increasingly integrated Project Portfolio Management (PPM) suites for strategically aligning and planning IT projects, and for controlling application portfolio costs. The dynamic PPM market is poised for an annual growth rate of 12% to 20% through year end 2012, as users seek to tie strategies more effectively to planning and control—including IT strategy. As shown in Figure 16, the top four PPM vendors worldwide in 2007, in terms of total software revenue, were (in order) Microsoft, Primavera Systems, CA and Planview. These top four vendors held 46% of the total worldwide PPM market share in 2007, with revenue of more than $512 million (copyright Gartner Group, 2008).

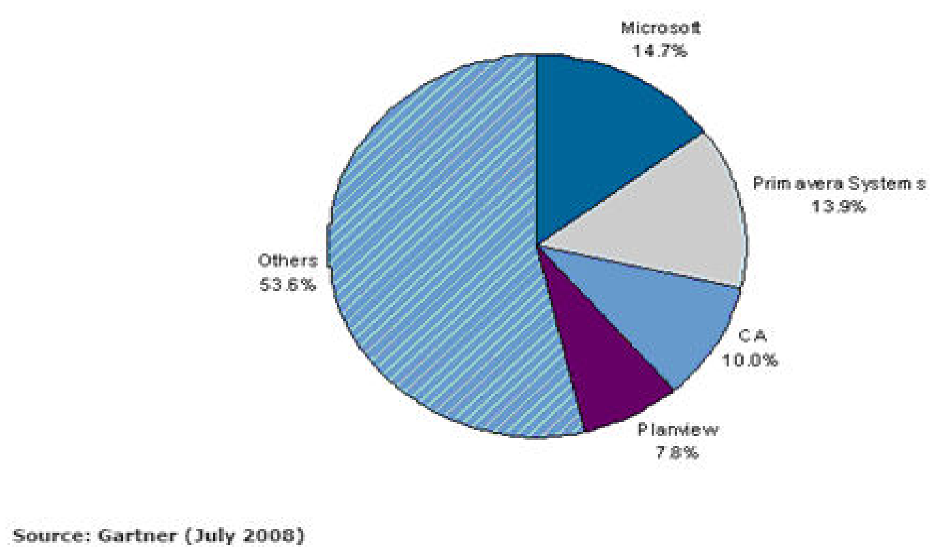


Figure 16. Top Four PPM Vendors Worldwide in 2007

Our research team will research the top four PPM solutions and a employ a vertically focused Risk Management solution to evaluate which is the best or if none are capable of providing an all-in-one solution. Our analysis will not only require program management but critical portfolio, decision, analysis and the ability to provide DoD analysis capability.

a. COTS PPM Suite#1: Microsoft Project Portfolio Management Program

Microsoft provides an interesting approach to PPM, with use of its Office Project Portfolio Server (OPPS) 2007, which assists organizations in realizing its potential by identifying, selecting, managing, and delivering portfolios that align with strategic priorities.

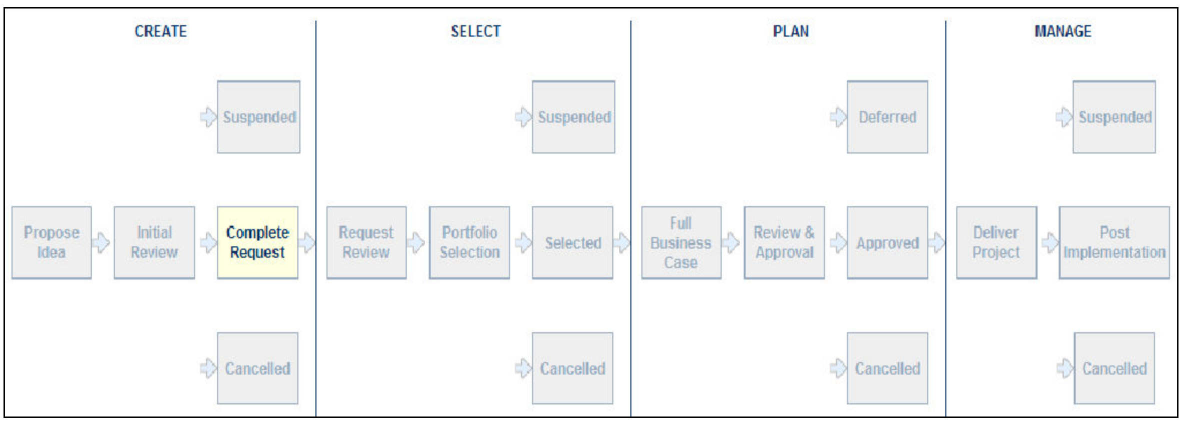


Figure 17. OPPS 2007 Workflow Design

Figure 17 above includes an intuitive workflow design as part of a tracking tool that is designed for project/program managers to define control points to multiple workflows. The control points govern life cycle phases used as a common denominator to aggregate and report on projects across various fields. The beauty of this deliverable is that it receives managerial signature before moving forward in the life cycle phases. This audit functionality makes stakeholders aware and accountable as projects move from ideas to consideration to implementation.

Figure 18 below describes analysis techniques that create rapid assessments of the impact on the portfolio's business value and effectively communicates the tradeoffs, including the listed projects within a portfolio.

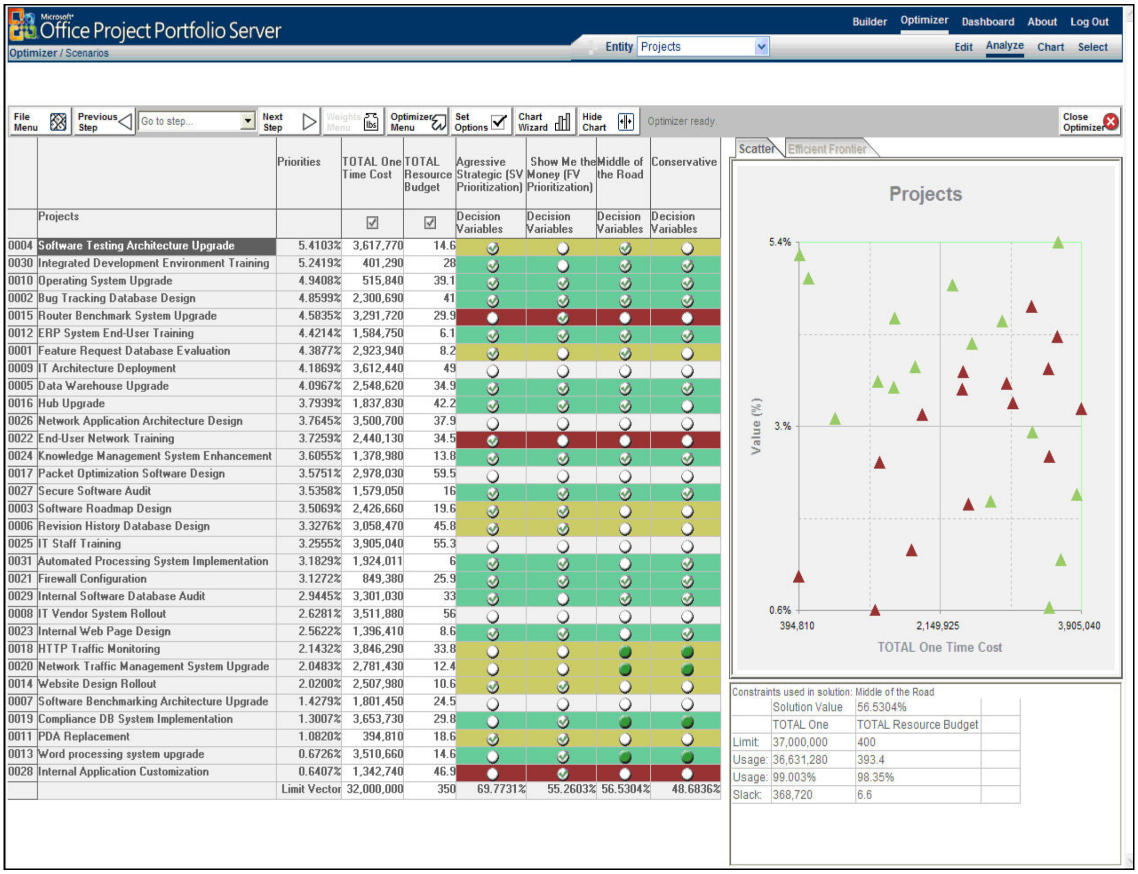


Figure 18. Analysis Techniques for Rapid Assessment of Impact on the Portfolio's Business Value

Figure 19 below is an example of a tracking tool from OPPS, which is designed to measure and track projects, programs, and applications throughout their life cycle. This provides the visibility to proactively identify potential issues, promote decision making, and help ensure that the organization portfolios deliver maximum business value.

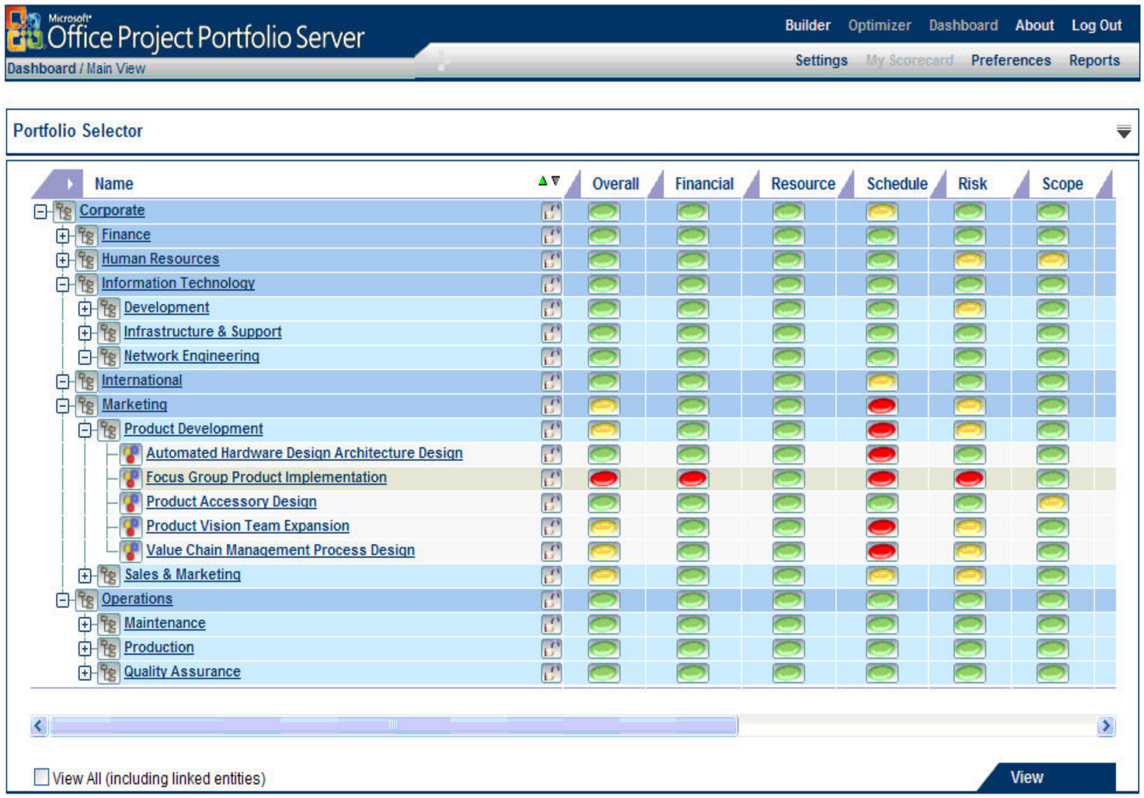


Figure 19. Sample OPPS Tool for Measuring and Tracking Projects/Programs/Applications Throughout Their Life Cycle

OPPS is designed to support open architecture, enabling integration with Microsoft Office Project Server 2007 and other PPM COTS applications to provide organizations with an end-to-end project portfolio management solution. The bi-directional gateway enables administrators to link multiple Microsoft Office Project Servers to OPPS 2007, providing managers with a consolidated view of all projects within the organization.

In summary, Microsoft optimizes the use of OPPS and selects portfolios that best align with an organization's strategic priorities. The interface provided is user-friendly, and embeds best practice methodologies and analytical techniques to ensure selection of the right investments for business solutions. Microsoft shares its Corporate Project Solutions, allowing organizations to:

- Employ sophisticated optimization algorithms to select the optimal portfolio under varying budget constraints, such as costs and Full Time Equivalents (FTEs).

- Identify and break the constraints prohibiting the portfolio from reaching the Efficient Frontier.
- Automatically calculate the portfolio's alignment with an organization's business strategy.
- Enforce a rational, rather than emotional, approach to selecting portfolios.

(Microsoft PPM, 2009) provides a link to the Microsoft PPM Web site on the Internet.

b. COTS PPM Suite #2: Primavera Systems Project Portfolio Management

Customers use Primavera as a project, resource and portfolio management solution to propose, prioritize, and select strategic investments and then to plan, manage and control the entire portfolio of projects through to successful completion. Primavera solutions are industry-specific and role-based, with a design powered to support global enterprises. Primavera PPM product can be used to manage any type of portfolio, including:

- IT project requests
- Applications for rationalization
- New product development
- Capital programs

As depicted in Figure 20 and Figure 21, utilizing Microsoft Internet Explorer, Primavera's design supports everything from data entry forms for details about a single investment, to scorecards for evaluating a set of investments in a portfolio, to investor maps for reviewing and analyzing a portfolio of investments, or even evaluating a portfolio of portfolios.

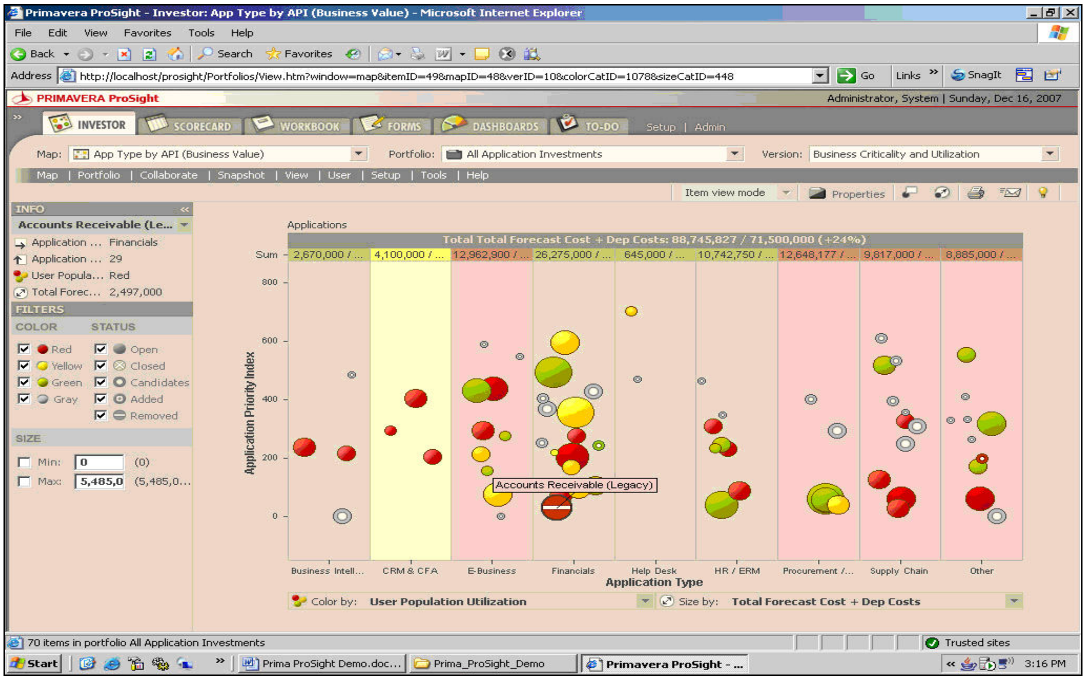


Figure 20. Sample Primavera Project Portfolio Management Tool

The key aspect of Primavera PPM is that it is specifically designed for proposing, planning, and controlling portfolios of investments in a collaborative way, following an objective and transparent process. These results propose enormous gains in efficiencies and improvements in business performance.

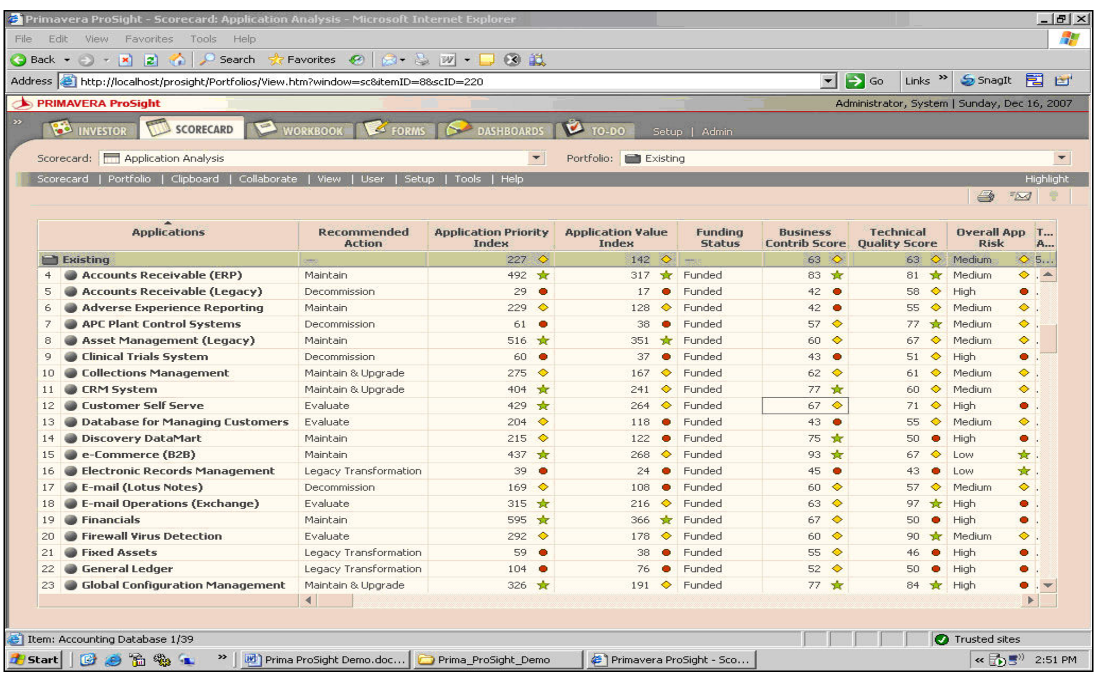


Figure 21. Primavera PPM Sample Application Analysis

In summary, Primavera PPM provides portfolio management software solutions, with similar Microsoft flexibility and infrastructure for enterprise portfolio management. The unique functionality, real-world enterprise scalability, and unlimited configurability make Primavera PPM a viable solution for managing just about any type of portfolio from ideas through execution. It also is designed with powerful security features for clean user interface and collaboration among all organizational stakeholders. (Primavera PPM, 2009) provides a link to the Primavera PPM Web site on the Internet.

c. COTS PPM Suite #3: Planview Portfolio Management Program

Planview has designed tools to identify project requirements, manage the scope of work, and minimize change. These tools provide more visibility into how a project can stay on track and deliver real business value. The Planview PPM COTS application was designed to provide capabilities to ensure:

- Optimization of resources enterprise-wide
- Integrated decision making
- Ability to view project performance and perform trend analysis
- Mitigation of risks and management of changes

As depicted in Figure 22 below, Planview PPM COTS application design assists in balancing portfolios, supporting management decisions for the proper allocation of work to the most appropriate personnel. By managing work with this portfolio, one can deliver the highest business value to projects across an organization.

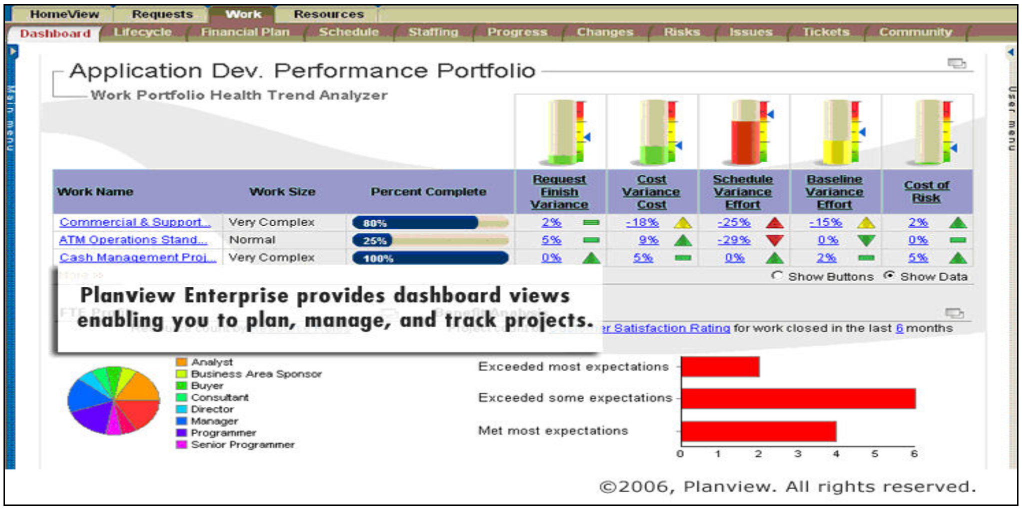


Figure 22. Planview PPM Application Development Performance Portfolio

In addition, project budgets must be forecasted, baselined, and managed throughout the project life cycle. With Planview Enterprise, IT financial managers, the PMO and project managers can collaborate to better forecast costs and monitor spending through actual resource assignments and reported time. The key is the establishment of integration with existing financial and accounting systems with Microsoft, as depicted in Figure 23 below.

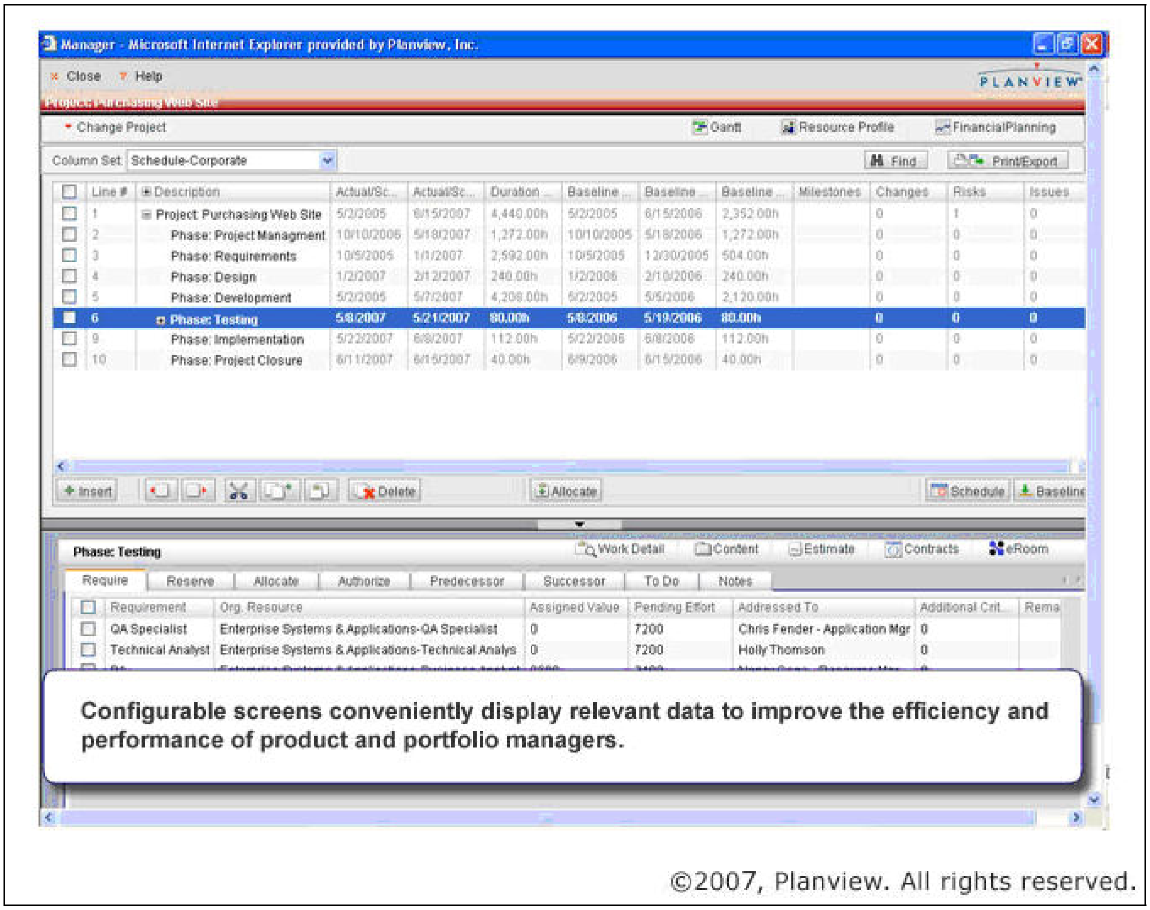


Figure 23. Planview Enterprise Tool for Forecasting Costs and Monitoring Spending

Plainview is designed to help technology organizations deliver value through a comprehensive, systematic approach to:

- Measuring and analyzing current performance,
- Comparing actual results with clearly defined business requirements,
- Analyzing and documenting decisions, and
- Efficiently executing change initiatives.

(Plainview PPM, 2008) provides a link to the Planview PPM Web site on the Internet.

d. COTS PPM Suite#4: CA Project Portfolio Management

The CA PPM approach facilitates collaborative projects between organizations and CA, based on repeatable best practices guided by forecasted implementation from leadership.

During the design and development process, CA and CA strategic partners work together with organizations to:

- Assess and prioritize requirements,
- Create a requirements specification and project plan,
- Architect a process and technical design and implementation blueprint to improve maturity,
- Install, configure, integrate and test a solution "as built" for environments and improve processes, and
- Deliver quality results quickly in 30 days or less in order to achieve rapid time-to-value and improved business alignment.

In addition, like any project, CA PPM focuses on strong sponsorship from senior management, along with representation from the various stakeholders within the organization who understand the drive needed to help cultivate the business benefits of enhanced change. CA uses a deployment methodology which is certified to align organization PPM capabilities and designs for strategic service life cycle management goals. Below are some CA focal points that are designed for PPM solutions:

a. Achieve Rapid Time-to-Value through repeatable scoping models and gap analysis that identify role-based business objectives, requirements and configuration designs, plus deployment methodologies that apply and adapt the pre-defined configurations of CA Services Accelerators to deliver a custom CA PPM solution.

b. Implement Multi-phased Deployments with a goal of 60-90 day increments so you can continually deliver IT service value and improve the maturity of your CA PPM solution without overwhelming your organization with change and excessive adoption challenges.

c. Stabilize your Solution at the End of Deployment phases to maximize your current investment. Consultants tune your CA PPM solution, provide administrative knowledge transfer to your IT staff and solution overviews for your end users, assist with production rollout and make recommendations that can speed adoption or further develop your CA PPM solution maturity and business value.

d. With On-boarding Services from CA Education, you can achieve expected productivity gains and increase adoption rates. A robust selection of prepared courses delivered in a variety of formats and options, custom-designed courses, and the CA Productivity Accelerator (a context-sensitive, customizable training solution) provide focused, ongoing education support to speed adoption of your CA PPM solution.

The touted benefits of CA PPM are designed to provide:

- Lower risk from experience and best practices.
- Faster results through incremental deployment methodologies, self-service support knowledge and in-context and online training.
- Improved outcomes with thought leadership and proven experience.
- Knowledgeable administrators and users from deployment on-boarding, continuing education and support guidance.

(CA PPM, 2008) provides a link to the CA PPM Web site on the Internet.

4. Forrester Research COTS PA Product Landscape

The Forrester Wave™ Project Portfolio Management Tools, Q4 2007 report established CA as the PPM leader in 2007, according to an article published 18 December 2007, by Mr. Lewis Cardin et al. (p. 8). Forrester evaluated fourteen leading PPM vendors across ninety-five criteria and found that CA and Planview established PPM leadership within the field thanks to their wide choice of mature features and functions. Forrester's COTS PA product research uncovered a market environment in which:

- CA, Planview, HP, Primavera, and IBM lead the pack
- Compuware, Oracle, Serena, and Microsoft offer competitive options
- SAP and Daptiv lack the expected full suite of out-of-the-box offerings

This evaluation of the COTS PPM Suite market is intended to be a starting point only. Readers are encouraged to view detailed product evaluations and adapt the criteria weightings to suit their individual needs through the Forrester™ Wave Excel-based vendor comparison tool (see Figure 24).

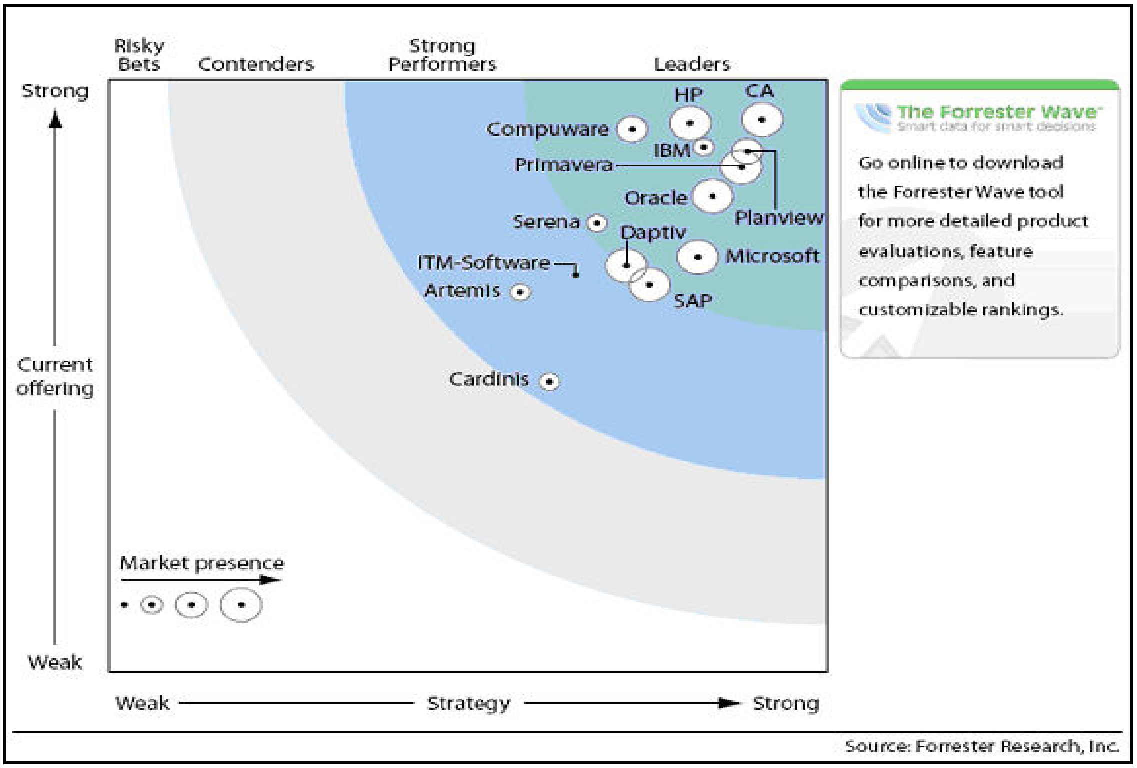


Figure 24. Forrester™ Wave Portfolio Management Tools, Q4' 07

As the front runner, CA is not alone and, by far, has not cornered the market in the PPM arena. However, as shown above, growth is taken seriously by all players to become the best in an economy that could use leadership. Below are company profiles that contributed to their PPM leadership roles:

- **Microsoft** moves into the leader zone. Microsoft has had some mountains to climb with its integration of UMT (a premier portfolio management application) and getting off its thick client workstation solution for project management. Microsoft has succeeded in gluing these projects and portfolio management solutions together, along with the advent of its server technology. While it's reporting capabilities continue to excel (no pun intended), its customers will benefit from further development in its methodology offering and increased financial management capability, particularly in the area of chargeback (Microsoft Advances As A Leader In The PPM Market (Cardin, Lewis, Forrester Wave, 2007).

- **Primavera** continues to keep a stronghold with its demand management, workflow, and methodology software; it must develop more depth in its Application Portfolio Management and infrastructure portfolio management offerings to be as equally attractive to its IT customers as it is with rest of the enterprise (Primavera Is A Leader In The Large Enterprise PPM Market, (Cardin, L., Cullen, A., & Cecere, M., 2007).

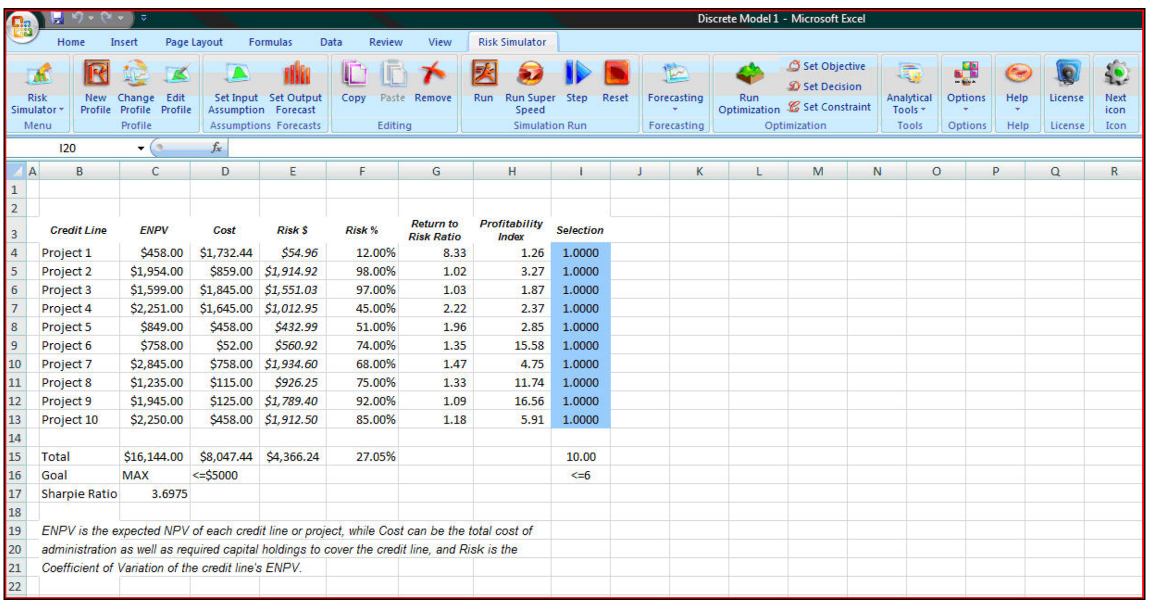
- **Planview** continues to be in front in the specific area of portfolio management and is neck and neck with Primavera on project and portfolio management methodology. Planview still has some work to do with its integrated IT management offering (Planview Is An Undeniable Leader In The PPM Market, (Cardin, L. Cullen, A., & Cecere, M., 2007).

- **CA's** continued strength in reporting and its focus on enterprise IT management makes PPM an integral part of overall customer IT management (CA Leads in Many Offerings in the PPM Market (Cardin, L., Cullen, A., & Cecere, M., 2007).

5. Real Options Valuation's Risk Simulator

Real Options Valuation's Risk Simulator software package will help to identify, quantify, and evaluate risk in projects and decisions. Risk Simulator, a powerful Excel add-in application, is used for applying simulation, forecasting, statistical analysis, and optimization in existing Excel spreadsheet models. It contains four different modules: Monte Carlo Simulation, Optimization, Statistical and Analytical tools, Time Series and Cross-Sectional forecasting. Risk simulator is also integrated with the Real Options Super Lattice Solver software, for solving strategic real options, financial options, and employee stock options.

Figures 25 through 29 depict sample optimization models which were run with Risk Simulator, both before and after optimization. Figure 25 is a discrete model that uses a static optimization which is run on static models, no assumption inputs, without simulations. This type of optimization is usually run to determine the initial optimal portfolio before more advanced optimizations are applied.

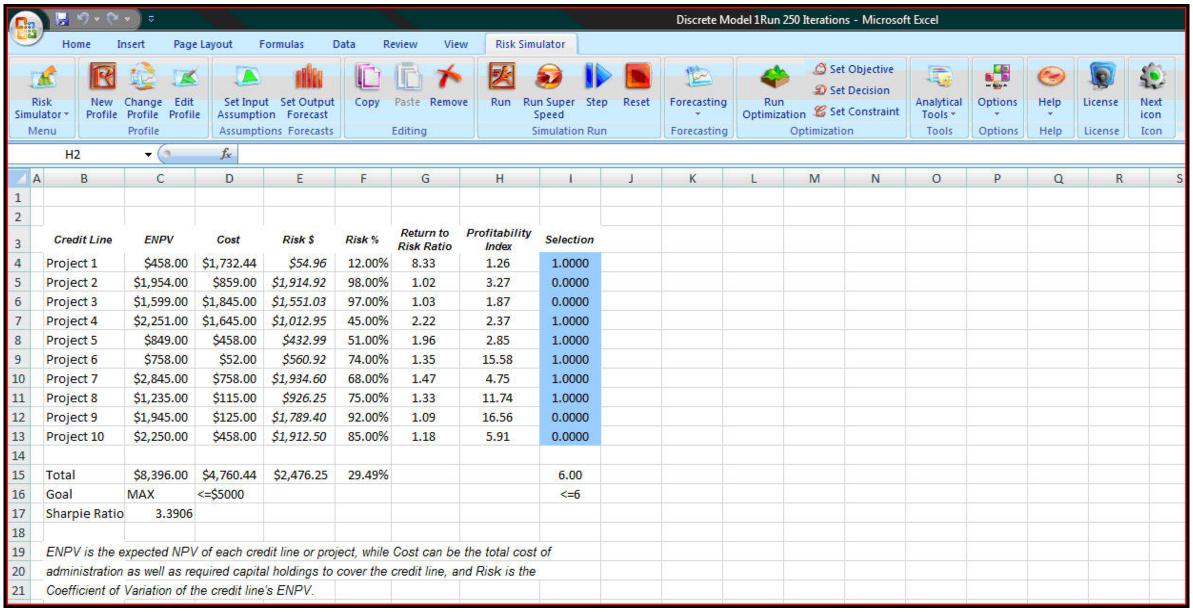


Credit Line	ENPV	Cost	Risk $	Risk %	Return to Risk Ratio	Profitability Index	Selection
Project 1	$458.00	$1,732.44	$54.96	12.00%	8.33	1.26	1.0000
Project 2	$1,954.00	$859.00	$1,914.92	98.00%	1.02	3.27	1.0000
Project 3	$1,599.00	$1,845.00	$1,551.03	97.00%	1.03	1.87	1.0000
Project 4	$2,251.00	$1,645.00	$1,012.95	45.00%	2.22	2.37	1.0000
Project 5	$849.00	$458.00	$432.99	51.00%	1.96	2.85	1.0000
Project 6	$758.00	$52.00	$560.92	74.00%	1.35	15.58	1.0000
Project 7	$2,845.00	$758.00	$1,934.60	68.00%	1.47	4.75	1.0000
Project 8	$1,235.00	$115.00	$926.25	75.00%	1.33	11.74	1.0000
Project 9	$1,945.00	$125.00	$1,789.40	92.00%	1.09	16.56	1.0000
Project 10	$2,250.00	$458.00	$1,912.50	85.00%	1.18	5.91	1.0000
Total	$16,144.00	$8,047.44	$4,366.24	27.05%			10.00
Goal	MAX	<=$5000					<=6
Sharpie Ratio	3.6975						

ENPV is the expected NPV of each credit line or project, while Cost can be the total cost of administration as well as required capital holdings to cover the credit line, and Risk is the Coefficient of Variation of the credit line's ENPV.

Figure 25. Sample Optimization Model Run with Risk Simulator (Discrete Model)

Note that the selection criteria are all "ones." The decision criteria for this model is to select six of the best projects based on risk and cost, with a cost limit of less than $5000. Figure 26 below is the same model after being run through 250 iterations and evaluating the risk/cost factors to make the best decision.

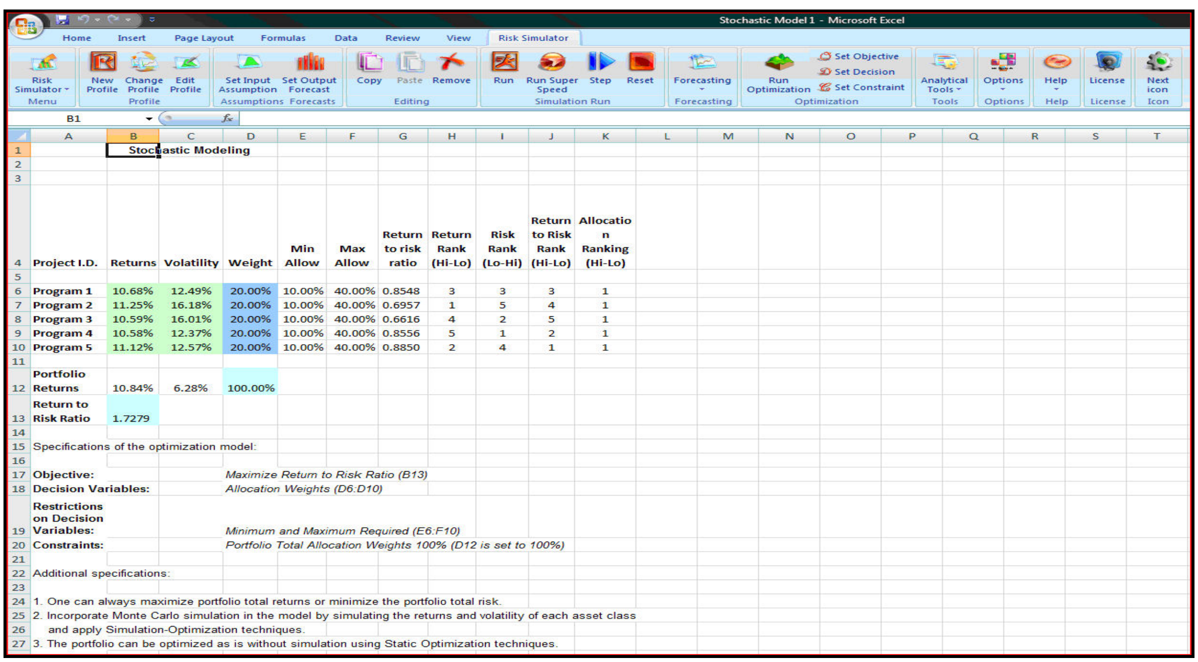


Credit Line	ENPV	Cost	Risk $	Risk %	Return to Risk Ratio	Profitability Index	Selection
Project 1	$458.00	$1,732.44	$54.96	12.00%	8.33	1.26	1.0000
Project 2	$1,954.00	$859.00	$1,914.92	98.00%	1.02	3.27	0.0000
Project 3	$1,599.00	$1,845.00	$1,551.03	97.00%	1.03	1.87	0.0000
Project 4	$2,251.00	$1,645.00	$1,012.95	45.00%	2.22	2.37	1.0000
Project 5	$849.00	$458.00	$432.99	51.00%	1.96	2.85	1.0000
Project 6	$758.00	$52.00	$560.92	74.00%	1.35	15.58	1.0000
Project 7	$2,845.00	$758.00	$1,934.60	68.00%	1.47	4.75	1.0000
Project 8	$1,235.00	$115.00	$926.25	75.00%	1.33	11.74	1.0000
Project 9	$1,945.00	$125.00	$1,789.40	92.00%	1.09	16.56	0.0000
Project 10	$2,250.00	$458.00	$1,912.50	85.00%	1.18	5.91	0.0000
Total	$8,396.00	$4,760.44	$2,476.25	29.49%			6.00
Goal	MAX	<=$5000					<=6
Sharpie Ratio	3.3906						

ENPV is the expected NPV of each credit line or project, while Cost can be the total cost of administration as well as required capital holdings to cover the credit line, and Risk is the Coefficient of Variation of the credit line's ENPV.

Figure 26. Sample Optimization Model Run with Risk Simulator (After Run Through 250 Iterations)

Figure 27 below is a sample of a Stochastic Model, which can be run either by dynamic optimization or by stochastic optimization. Dynamic optimization is a first-run simulation. The results of the simulation are applied to the model, and then an optimization is applied to the simulated values.



Stochastic Modeling

Project I.D.	Returns	Volatility	Weight	Min Allow	Max Allow	Return to risk ratio	Return Rank (Hi-Lo)	Risk Rank (Lo-Hi)	Return to Risk Rank (Hi-Lo)	Allocation Ranking (Hi-Lo)
Program 1	10.68%	12.49%	20.00%	10.00%	40.00%	0.8548	3	3	3	1
Program 2	11.25%	16.18%	20.00%	10.00%	40.00%	0.6957	1	5	4	1
Program 3	10.59%	16.01%	20.00%	10.00%	40.00%	0.6616	4	2	5	1
Program 4	10.58%	12.37%	20.00%	10.00%	40.00%	0.8556	5	1	2	1
Program 5	11.12%	12.57%	20.00%	10.00%	40.00%	0.8850	2	4	1	1
Portfolio Returns	10.84%	6.28%	100.00%							
Return to Risk Ratio	1.7279									

Specifications of the optimization model:

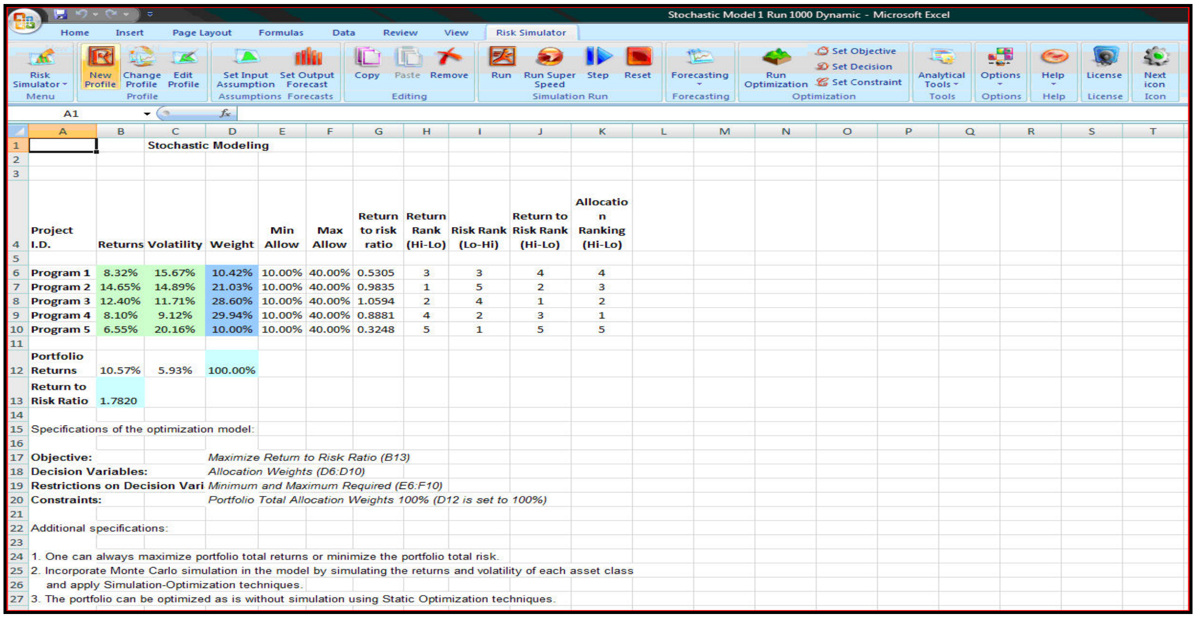
Objective: *Maximize Return to Risk Ratio (B13)*
Decision Variables: *Allocation Weights (D6:D10)*
Restrictions on Decision Variables: *Minimum and Maximum Required (E6:F10)*
Constraints: *Portfolio Total Allocation Weights 100% (D12 is set to 100%)*

Additional specifications:

1. One can always maximize portfolio total returns or minimize the portfolio total risk.
2. Incorporate Monte Carlo simulation in the model by simulating the returns and volatility of each asset class and apply Simulation-Optimization techniques.
3. The portfolio can be optimized as is without simulation using Static Optimization techniques.

Figure 27. Sample Optimization Model Run with Risk Simulator (Stochastic Model)

Figure 28 below is the same model run through the dynamic optimization with 1000 simulation trials.



Stochastic Model 1 Run 1000 Dynamic - Microsoft Excel

Stochastic Modeling

Project I.D.	Returns	Volatility	Weight	Min Allow	Max Allow	Return to risk ratio	Return Rank (Hi-Lo)	Risk Rank (Lo-Hi)	Return to Risk Rank (Hi-Lo)	Allocation Ranking (Hi-Lo)
Program 1	8.32%	15.67%	10.42%	10.00%	40.00%	0.5305	3	3	4	4
Program 2	14.65%	14.89%	21.03%	10.00%	40.00%	0.9835	1	5	2	3
Program 3	12.40%	11.71%	28.60%	10.00%	40.00%	1.0594	2	4	1	2
Program 4	8.10%	9.12%	29.94%	10.00%	40.00%	0.8881	4	2	3	1
Program 5	6.55%	20.16%	10.00%	10.00%	40.00%	0.3248	5	1	5	5
Portfolio Returns	10.57%	5.93%	100.00%							
Return to Risk Ratio	1.7820									

Specifications of the optimization model:

Objective: *Maximize Return to Risk Ratio (B13)*
Decision Variables: *Allocation Weights (D6:D10)*
Restrictions on Decision Vari *Minimum and Maximum Required (E6:F10)*
Constraints: *Portfolio Total Allocation Weights 100% (D12 is set to 100%)*

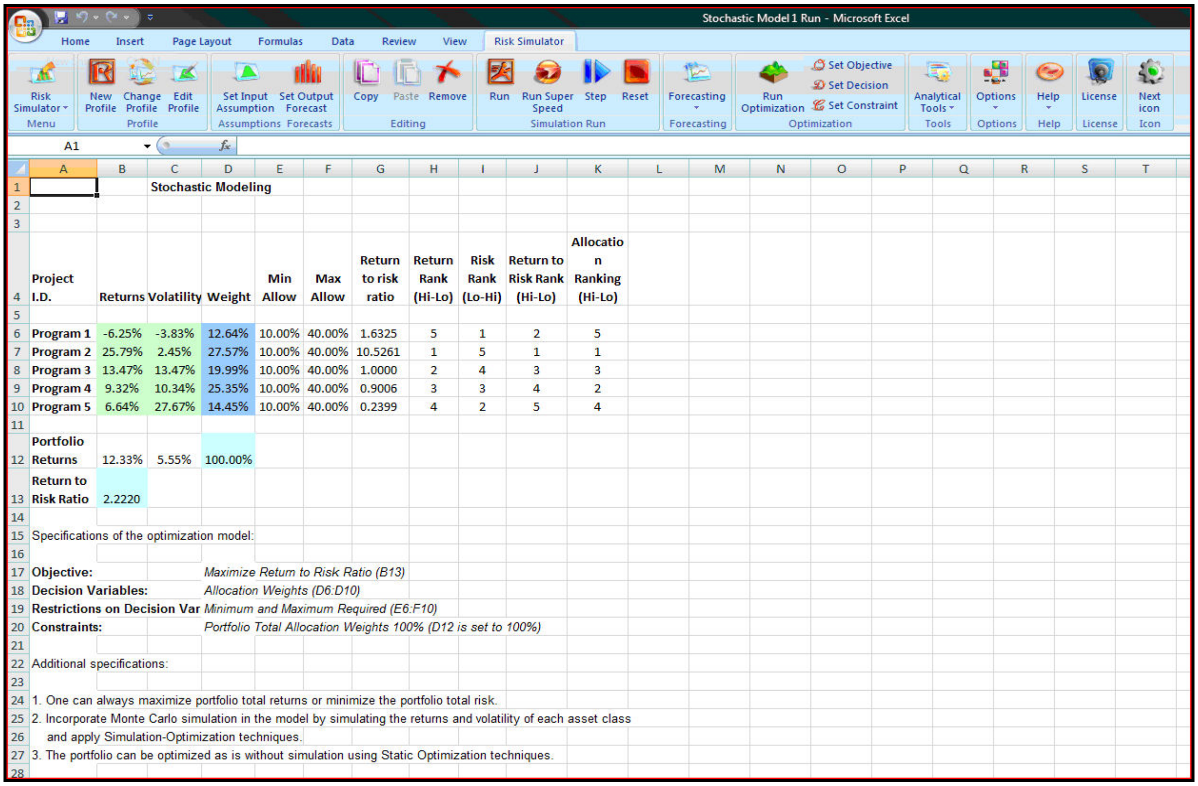
Additional specifications:

1. One can always maximize portfolio total returns or minimize the portfolio total risk.
2. Incorporate Monte Carlo simulation in the model by simulating the returns and volatility of each asset class and apply Simulation-Optimization techniques.
3. The portfolio can be optimized as is without simulation using Static Optimization techniques.

Figure 28. Sample Optimization Model Run with Risk Simulator (Dynamic Optimization with 1000 Simulation Trials)

Note that the rankings have changes based on the simulations comparing the input assumptions (green boxes) and the decision criteria (blue box). The light blue boxes are the objective, risk return ratio (B13), and the constraint (100%, (D12)).

Stochastic optimization is similar to dynamic optimization, except that the process is repeated several times. The final decision variables will each have their own forecast chart indicating their optimal range. Figure 29 below is the same model run through the stochastic optimization with 1000 simulation trials and 20 optimization runs.



Project I.D.	Returns	Volatility	Weight	Min Allow	Max Allow	Return to risk ratio	Return Rank (Hi-Lo)	Risk Rank (Lo-Hi)	Return to Risk Rank (Hi-Lo)	Allocation Ranking (Hi-Lo)
Program 1	-6.25%	-3.83%	12.64%	10.00%	40.00%	1.6325	5	1	2	5
Program 2	25.79%	2.45%	27.57%	10.00%	40.00%	10.5261	1	5	1	1
Program 3	13.47%	13.47%	19.99%	10.00%	40.00%	1.0000	2	4	3	3
Program 4	9.32%	10.34%	25.35%	10.00%	40.00%	0.9006	3	3	4	2
Program 5	6.64%	27.67%	14.45%	10.00%	40.00%	0.2399	4	2	5	4
Portfolio Returns	12.33%	5.55%	100.00%							
Return to Risk Ratio	2.2220									

Specifications of the optimization model:

Objective: *Maximize Return to Risk Ratio (B13)*
Decision Variables: *Allocation Weights (D6:D10)*
Restrictions on Decision Var *Minimum and Maximum Required (E6:F10)*
Constraints: *Portfolio Total Allocation Weights 100% (D12 is set to 100%)*

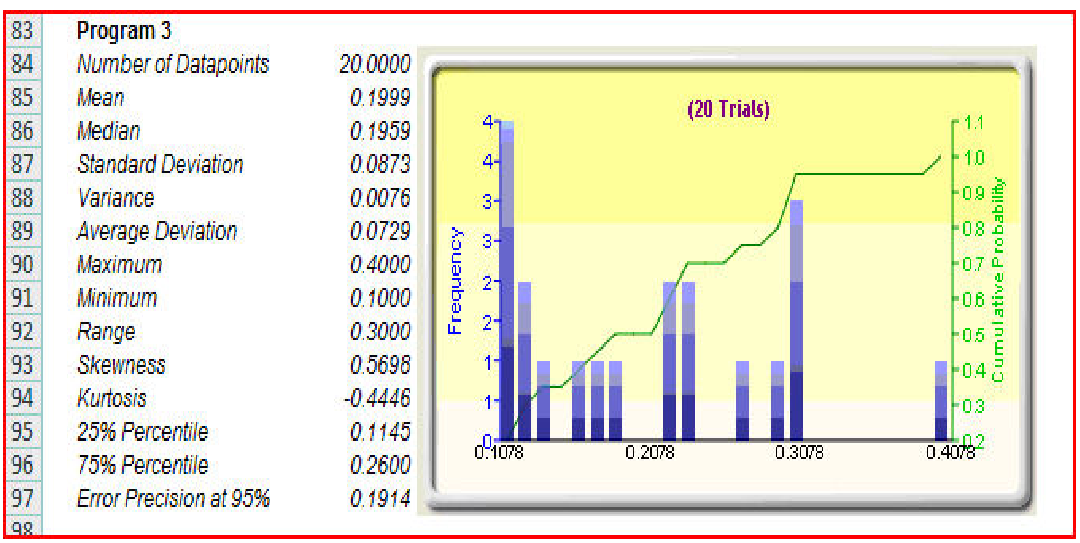
Additional specifications:

1. One can always maximize portfolio total returns or minimize the portfolio total risk.
2. Incorporate Monte Carlo simulation in the model by simulating the returns and volatility of each asset class and apply Simulation-Optimization techniques.
3. The portfolio can be optimized as is without simulation using Static Optimization techniques.

Figure 29. Sample Optimization Model Run with Risk Simulator (Stochastic Model with 1000 Simulation Trials and 20 Optimization Runs)

Again, note the changes in the rankings and the objective.

Figure 30 below depicts the statistical results of the optimization for Program 3, with 20 data points.



Program 3	
Number of Datapoints	20.0000
Mean	0.1999
Median	0.1959
Standard Deviation	0.0873
Variance	0.0076
Average Deviation	0.0729
Maximum	0.4000
Minimum	0.1000
Range	0.3000
Skewness	0.5698
Kurtosis	-0.4446
25% Percentile	0.1145
75% Percentile	0.2600
Error Precision at 95%	0.1914

Figure 30. Statistical Results of Optimization for Program 3 (with 20 Data Points)

The Risk Simulation software provides a risk/decision analysis to help any business make better decisions, both now and in the future.

Efficient Frontier (EF) analysis, shown in Figure 31 below, is the process of re-running multiple optimizations with different constraints and each optimal portfolio is a point on the frontier. To run the analysis, click on the Constraints icon or in Risk Simulator, select Optimization and Constraints. Then add as many changing constraints as desired to generate multiple EFs.

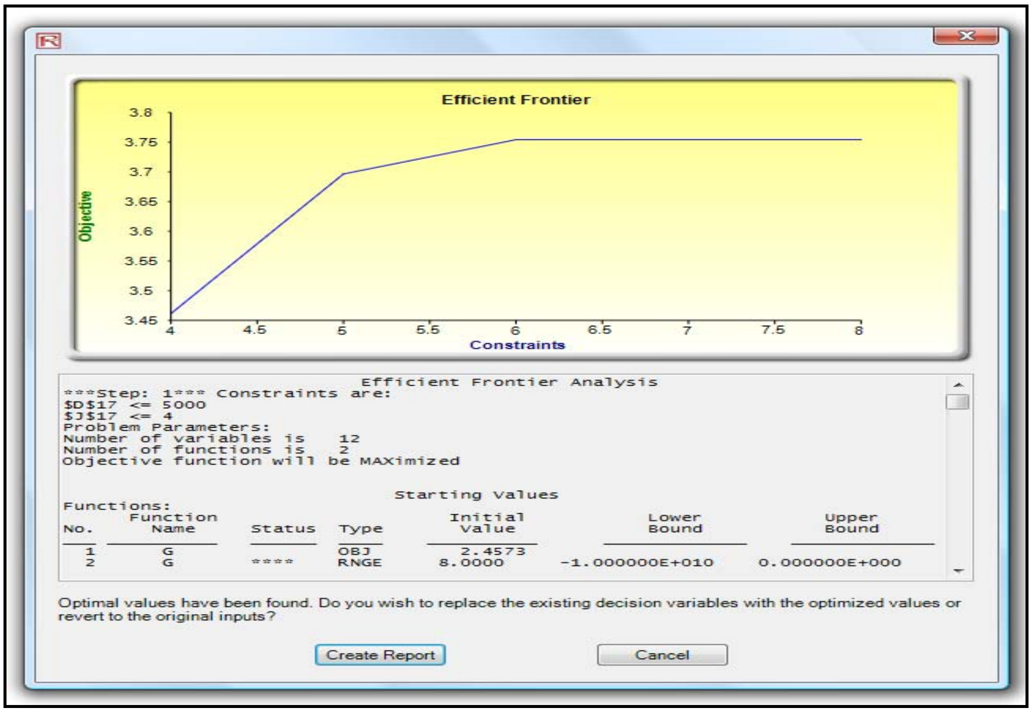


Figure 31. Efficient Frontier

6. **Palisade @RISK (http://www.palisade.com/)**

Palisade @RISK performs risk analysis using Monte Carlo simulation to show you many possible outcomes using Microsoft Excel spreadsheets, and tells you how likely outcomes are to occur. You can then decide which risks are worth taking and which ones to avoid, allowing for improved decision making under uncertainty. @RISK uses simulation to answer questions like:

a. “What is the probability of profit exceeding $10 million?”

b. “What are the chances of losing money on this venture?”

c. “What is the probability that the project will be delivered within budget?”

d. “How much contingency (management reserve) should be included?”

@RISK is an add-in to Microsoft Excel, integrating completely with the spreadsheet. All @RISK functions are Excel functions, and behave exactly the same as native Excel functions. @RISK windows are all linked directly to cells in your spreadsheet, so changes in one place are carried over to the other. @RISK graphs point to their cells via callout windows. Figure 32 depicts an @RISK probability distribution for a sample project.

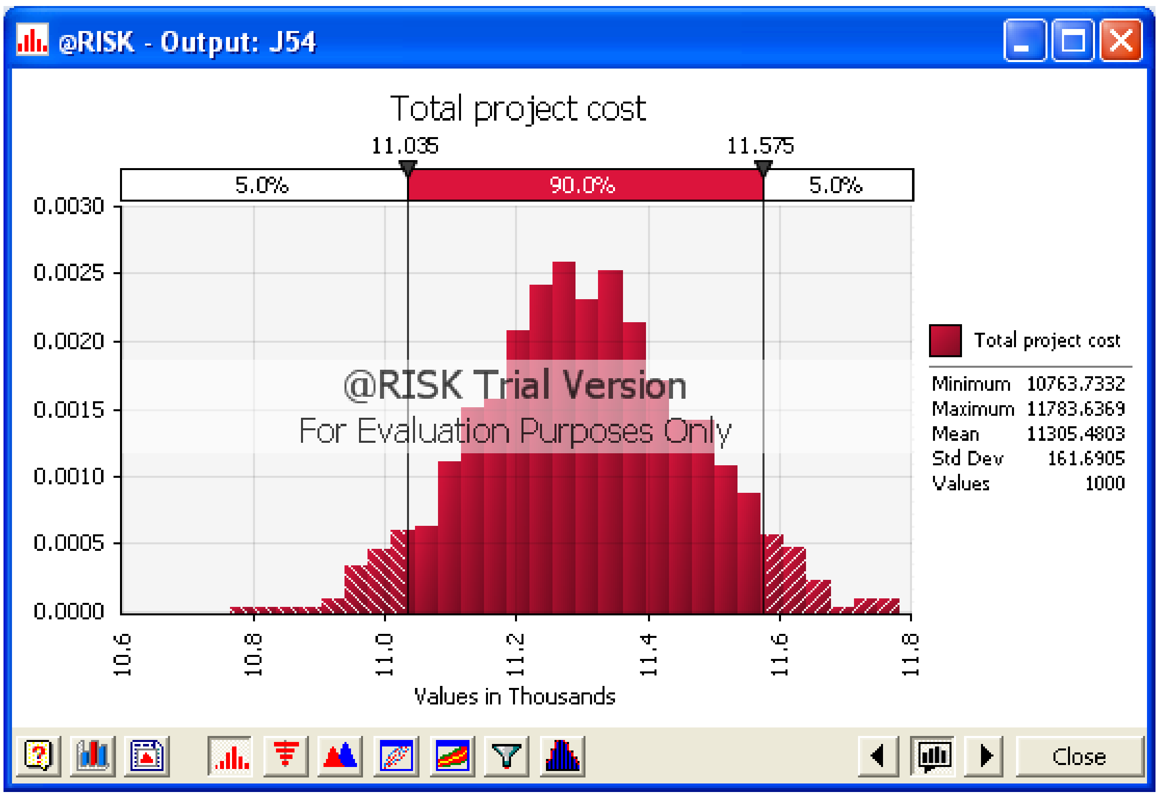


Figure 32. @RISK Probability Distribution

7. Shortcomings of COTS Products

The drive to incorporate COTS software and hardware is often based on incomplete or inaccurate information. Clearly identified requirements that cannot incorporate COTS software and hardware need additional research, cost, and development within their product design. However, using PPM COTS products does offer many advantages and disadvantages. For instance, many of these shortcomings are described by engineers who are reluctant to move to COTS, if for no other reason than a general resistance to change. Many engineers display the attitude “if we did not make it; the product design is no good.” It is basically that type of mentality that promotes a general distrust of COTS products.

a. Advantages of COTS

The advantages associated with the use of COTS are:

- Immediately available and shorter development schedule
- Reduced cost
- Increased portability
- Improved Quality (resulting from more efficient testing)

b. Disadvantages of COTS

The disadvantages associated with the use of COTS are:

- Hard to meet special requirements
- Continual investment in COTS product
- Bad interoperability

Although it is generally a good idea not to accept a product without verifying its capabilities, it is also not a good idea to reject a product on general principle. Below are the shortcomings of discussed COT products and assumptions about their acceptable levels of requirements that need to be or have been adjusted for product/solution.

a. Microsoft’s design lacked Portfolio management requirements to gather accurate data, which led to the acquisition of UMT. This compensated for the needed solution and supported the project management software deployed in late 2007.

b. Primavera has mastered the art of determining trends in the PPM market, identifying the PPM needs of its target markets, and acquiring solutions that fit the vendor’s ever changing and evolving products. The design has shortcomings that are ideally suited to large enterprises with mature PPM processes; design is not suited for requirements of smaller-sized businesses.

c. Plainview’s design is the second strongest portfolio management solution respected on the market.

d. CA is the leader and continuously moving up in its leadership position. Shortcomings are very limited to its continued investments in integrated IT management.

C. MODEL DEVELOPMENT

1. Model Data

Using the basic data depicted in Figure 33 below, our research team attempted to develop a model in (1) Real Options Valuation’s Risk Simulator and (2) @RISK that would analyze the data and provide usable output as measures of EMV. We also attempted to model this data with the Program Management (PM) software but were unable to do so. The EMV measures for this model were developed by our team. However, in practice, the EMV measures should be developed by Budget, Strategic, and Acquisition professionals to ensure their accuracy.

Program	ENPV	NPV	Cost	Strategy Ranking	Military Score	Tactical Score	FTE Resoucres
Program 1	$501.60	$102.30	$443.50	1.94	2.51	1.77	3.91
Program 2	$726.30	$121.30	$358.80	3.75	3.84	3.56	2.73
Program 3	$932.40	$354.20	$925.90	2.34	3.12	3.24	5.24
Program 4	$620.50	$265.80	$512.10	1.36	5.14	5.1	3.41
Program 5	$420.80	$271.20	$524.50	1.32	3.22	1.62	3.29
Program 6	$2,087.50	$345.90	$1,868.70	4.68	6.37	6.21	4.56
Program 7	$3,264.90	$594.10	$1,602.10	10.59	8.69	7.53	4.23
Program 8	$2,563.40	$421.50	$2,133.40	2.83	2.64	4.12	5.61
Program 9	$5,468.10	$1,032.20	$2,712.30	7.68	6.94	7.99	4.68
Program 10	$3,248.90	$775.40	$2,502.80	5.74	5.53	6.23	6.43
Program 11	$125.90	$32.80	$28.60	15.26	9.84	9.17	5.47
Program 12	$235.10	$85.60	$109.50	6.42	4.25	3.65	3.91
Program 13	$4,163.50	$325.10	$3,054.20	5.26	3.41	6.21	5.23
Program 14	$4,468.70	$594.10	$1,673.80	10.54	8.46	7.54	4.23
Program 15	$587.60	$421.50	$409.00	2.81	2.74	3.52	5.34
Program 16	$1,698.40	$431.90	$658.30	11.92	8.45	8.87	4.26
Program 17	$758.40	$134.20	$485.50	4.65	4.52	4.35	6.32
Program 18	$1,248.30	$301.50	$331.50	4.85	6.13	5.62	3.57
Program 19	$389.90	$26.10	$159.00	7.98	7.65	8.62	4.98
Program 20	$3,864.70	$1,257.60	$1,458.70	15.46	9.48	9.34	12.64
			$21,952.20	127.38	112.93	114.26	100.04
		Maximize	<=$10,500	<= 100			<= 80

Objective: *Maximize Total Portfolio Returns times the Portfolio Comprehensive Score*
Decision Variables: *Allocation or Go/No-Go Decision*
Restrictions on Decision Variables *Binary decision variables (0 or 1)*
Constraints: *Total Cost is less than $10,500 (in thousands or millions of dollars)*
Less than or equal to 10 projects selected in the entire portfolio
Full-time Equivalence resources have to be less than 80
Total Strategic Ranking for the entire portfolio must be less than 100

Figure 33. Base Evaluation Model

Earned Net Present Value is an enhancement of the NPV that explicitly addresses uncertainty. NPV compares a single stream of cash flows in today's dollars to the value of that same dollar in the future. Cost is the actual cost listed in the 2009 Defense Procurement Budget Request. Strategic Ranking, Military Score, and Tactical Score are EMV measures developed by evaluating the NDS and then scoring the programs based on how they meet the NDS. FTE resources equates to the amount of actual resources used as a percent. One hundred percent means that all resources are fully utilized all the time. The goal is to maximize the portfolio returns without exceeding an arbitrary budget of $10,500 while keeping the strategic ranking below 100 and the FTE below 80.

In evaluating this model, we plan to verify that PA and Defense budget decision making can be improved using COTS software.

2. Real Options Valuation's Risk Simulator

Figure 34 is the model developed using the Real Options Risk Simulator. The task was to run an optimization/simulation to determine which ten of the following twenty programs best meet the requirements outlined in the NDS. Only ten programs will go forward. These are real programs in the FY 2009 budget with the real costs included. The names of the real programs will be revealed later in the analysis section. The ranking and military/tactical scores, along with the FTE resources, are based on the NDS and the President's goals are located: http://www.whitehouse.gov/agenda/defense/.

Because our thesis is based on PA, we will attempt to run this through PPM programs as well as risk simulators. For the purpose of this model, the military score, comprehensive score, and tactical score are all measures of EMV.

After running the discrete (static) optimization on this model with the original budget of less than $10,500, and a strategy rank of less than 100, no more than ten programs, and FTE resources not to exceed 80.

Military Portfolio Optimization

Project Name	ENPV	NPV	Cost	Strategy Ranking	Return to Rank Ratio	Profitability Index	Selection	Military Score	Tactical Score	FTE Resources	Comprehensive Score
Project 1	$501.60	$102.30	$443.50	4.26	117.75	1.23	1	2.51	1.77	3.91	1.40
Project 2	$726.30	$121.30	$358.80	5.61	129.47	1.34	1	3.84	3.56	2.73	1.77
Project 3	$932.40	$354.20	$925.90	2.34	398.46	1.38	1	3.12	3.24	5.24	2.12
Project 4	$620.50	$265.80	$512.10	3.21	193.30	1.52	1	5.14	5.10	3.41	2.46
Project 5	$420.80	$271.20	$524.50	1.32	318.79	1.52	1	3.22	1.62	3.29	1.60
Project 6	$2,087.50	$345.90	$1,868.70	4.68	446.05	1.19	1	6.37	6.21	4.56	2.98
Project 7	$3,264.90	$594.10	$1,602.10	10.59	308.30	1.37	1	8.69	7.53	4.23	3.43
Project 8	$2,563.40	$421.50	$2,133.40	2.83	905.80	1.20	1	2.64	4.12	5.61	2.31
Project 9	$5,468.10	$1,032.20	$2,712.30	7.68	711.99	1.38	1	6.94	7.99	4.68	3.46
Project 10	$3,248.90	$775.40	$2,502.80	5.74	566.01	1.31	1	5.53	6.23	6.43	3.16
Project 11	$125.90	$32.80	$28.60	15.26	8.25	2.15	1	9.84	9.17	5.47	4.13
Project 12	$235.10	$85.60	$109.50	6.42	36.62	1.78	1	4.25	3.65	3.91	2.00
Project 13	$4,163.50	$325.10	$3,054.20	5.26	791.54	1.11	1	3.41	6.21	5.23	2.77
Project 14	$4,468.70	$594.10	$1,673.80	10.54	8.46	7.54	1	8.46	7.54	4.23	3.41
Project 15	$587.60	$421.50	$409.00	2.81	209.11	2.03	1	2.74	3.52	5.34	2.13
Project 16	$1,698.40	$431.90	$658.30	11.92	142.48	1.66	1	8.45	8.87	4.26	3.74
Project 17	$758.40	$134.20	$485.50	4.65	163.10	1.28	1	4.52	4.35	6.32	2.60
Project 18	$1,248.30	$301.50	$331.50	4.85	257.38	1.91	1	6.13	5.62	3.57	2.66
Project 19	$389.90	$26.10	$159.00	7.98	48.86	1.16	1	7.65	8.62	4.98	3.73
Project 20	$3,864.70	$1,257.60	$1,458.70	15.46	249.98	1.86	1	9.48	9.34	12.64	5.21
Total	$37,374.90		$21,952.20	133.41			20	**112.93**	**114.26**	100.04	**57.08**
Profit/Rank	$280.15										
Profit*Score	$2,133,370.83	Maximize	< =$10500	< =100			x <=10			<=80	

Figure 34. Real Programs in the FY09 Budget with Costs

Figure 35 shows the model after the initial optimization run including the ten selected programs. The model was then run several more times, changing the constraints of budget, and number of programs allowed. This information was then used to update the data in the efficient frontier charts below.

Military Portfolio Optimization

Project Name	ENPV	NPV	Cost	Strategy Ranking	Return to Rank Ratio	Profitability Index	Selection	Military Score	Tactical Score	FTE Resources	Comprehensive Score
Project 1	$501.60	$102.30	$443.50	4.26	117.75	1.23	0	2.51	1.77	3.91	1.40
Project 2	$726.30	$121.30	$358.80	5.61	129.47	1.34	0	3.84	3.56	2.73	1.77
Project 3	$932.40	$354.20	$925.90	2.34	398.46	1.38	0	3.12	3.24	5.24	2.12
Project 4	$620.50	$265.80	$512.10	3.21	193.30	1.52	0	5.14	5.10	3.41	2.46
Project 5	$420.80	$271.20	$524.50	1.32	318.79	1.52	0	3.22	1.62	3.29	1.60
Project 6	$2,087.50	$345.90	$1,868.70	4.68	446.05	1.19	0	6.37	6.21	4.56	2.98
Project 7	$3,264.90	$594.10	$1,602.10	10.59	308.30	1.37	1	8.69	7.53	4.23	3.43
Project 8	$2,563.40	$421.50	$2,133.40	2.83	905.80	1.20	0	2.64	4.12	5.61	2.31
Project 9	$5,468.10	$1,032.20	$2,712.30	7.68	711.99	1.38	1	6.94	7.99	4.68	3.46
Project 10	$3,248.90	$775.40	$2,502.80	5.74	566.01	1.31	1	5.53	6.23	6.43	3.16
Project 11	$125.90	$32.80	$28.60	15.26	8.25	2.15	1	9.84	9.17	5.47	4.13
Project 12	$235.10	$85.60	$109.50	6.42	36.62	1.78	1	4.25	3.65	3.91	2.00
Project 13	$4,163.50	$325.10	$3,054.20	5.26	791.54	1.11	0	3.41	6.21	5.23	2.77
Project 14	$4,468.70	$594.10	$1,673.80	10.54	8.46	7.54	1	8.46	7.54	4.23	3.41
Project 15	$587.60	$421.50	$409.00	2.81	209.11	2.03	0	2.74	3.52	5.34	2.13
Project 16	$1,698.40	$431.90	$658.30	11.92	142.48	1.66	1	8.45	8.87	4.26	3.74
Project 17	$758.40	$134.20	$485.50	4.65	163.10	1.28	1	4.52	4.35	6.32	2.60
Project 18	$1,248.30	$301.50	$331.50	4.85	257.38	1.91	1	6.13	5.62	3.57	2.66
Project 19	$389.90	$26.10	$159.00	7.98	48.86	1.16	1	7.65	8.62	4.98	3.73
Project 20	$3,864.70	$1,257.60	$1,458.70	15.46	249.98	1.86	0	9.48	9.34	12.64	5.21
Total	$20,906.60		$10,263.40	85.63			10	**70.46**	**69.57**	48.08	**32.32**
Profit/Rank	$244.15										
Profit*Score	$675,768.93	Maximize	< =$10500	< =100			x <=10			<=80	

Figure 35. Optimization with Ten (10) Programs

Figure 36 is a static efficiency frontier showing the EMV and ROI for the different constraint levels. This model was modified to include the percent ROI at the different constraint levels. Note that the baseline is annotated in red with an ROI of zero.

Static Efficiency Frontier

Budget	Comprehensive Score	Tactical Score	Military Score	Allowed Projects	ROI-RANK Objective	Percent Change ROI	
$9,500.00	32.37	69.03	70.16	9	$689,082.38	1.97%	
$10,500.00	32.32	69.57	70.46	10	$675,768.93	0.00%	Baseline
$11,500.00	35.82	72.59	73.34	11	$810,419.62	19.93%	
$12,500.00	39.27	81.77	80.68	12	$984,108.39	45.63%	
$13,000.00	40.59	84.01	82.20	13	$998,868.72	47.81%	

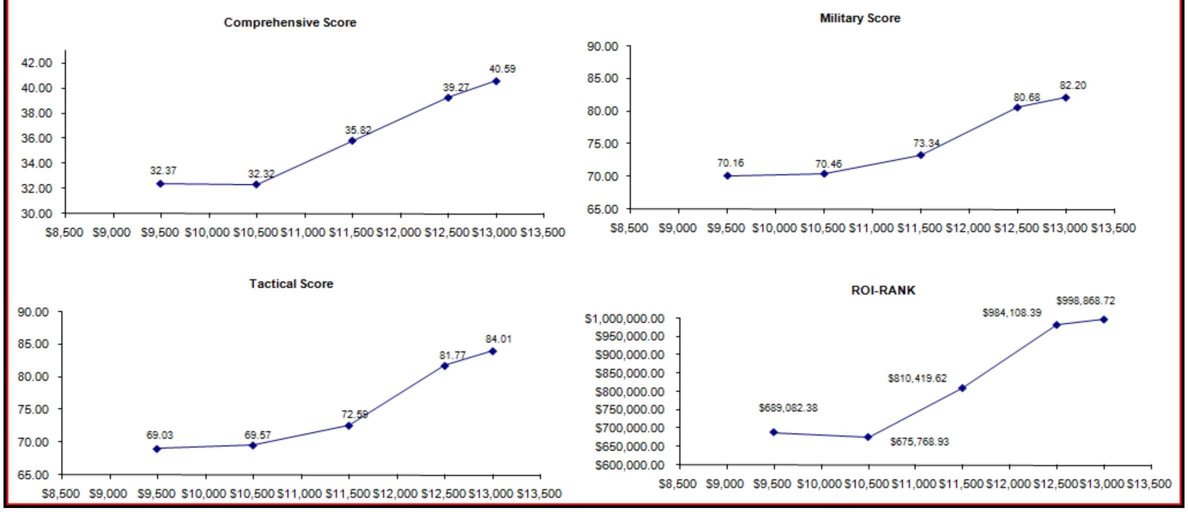


Figure 36. Efficient Frontiers with ROI

Military Portfolio Optimization

Project Name	ENPV	NPV	Cost	Strategy Ranking	Return to Rank Ratio	Profitability Index	Selection	Military Score	Tactical Score	FTE Resources	Comprehensive Score
Project 1	$501.60	$102.30	$443.50	4.26	117.75	1.23	0	2.51	1.77	3.91	1.40
Project 2	$726.30	$121.30	$358.80	5.61	129.47	1.34	0	3.84	3.56	2.73	1.77
Project 3	$932.40	$354.20	$925.90	2.34	398.46	1.38	0	3.12	3.24	5.24	2.12
Project 4	$620.50	$265.80	$512.10	3.21	193.30	1.52	1	5.14	5.10	3.41	2.46
Project 5	$420.80	$271.20	$524.50	1.32	318.79	1.52	0	3.22	1.62	3.29	1.60
Project 6	$2,087.50	$345.90	$1,868.70	4.68	446.05	1.19	0	6.37	6.21	4.56	2.98
Project 7	$3,264.90	$594.10	$1,602.10	10.59	308.30	1.37	1	8.69	7.53	4.23	3.43
Project 8	$2,563.40	$421.50	$2,133.40	2.83	905.80	1.20	1	2.64	4.12	5.61	2.31
Project 9	$5,468.10	$1,032.20	$2,712.30	7.68	711.99	1.38	1	6.94	7.99	4.68	3.46
Project 10	$3,248.90	$775.40	$2,502.80	5.74	566.01	1.31	0	5.53	6.23	6.43	3.16
Project 11	$125.90	$32.80	$28.60	15.26	8.25	2.15	1	9.84	9.17	5.47	4.13
Project 12	$235.10	$85.60	$109.50	6.42	36.62	1.78	0	4.25	3.65	3.91	2.00
Project 13	$4,163.50	$325.10	$3,054.20	5.26	791.54	1.11	0	3.41	6.21	5.23	2.77
Project 14	$4,468.70	$594.10	$1,673.80	10.54	8.46	7.54	1	8.46	7.54	4.23	3.41
Project 15	$587.60	$421.50	$409.00	2.81	209.11	2.03	1	2.74	3.52	5.34	2.13
Project 16	$1,698.40	$431.90	$658.30	11.92	142.48	1.66	1	8.45	8.87	4.26	3.74
Project 17	$758.40	$134.20	$485.50	4.65	163.10	1.28	1	4.52	4.35	6.32	2.60
Project 18	$1,248.30	$301.50	$331.50	4.85	257.38	1.91	1	6.13	5.62	3.57	2.66
Project 19	$389.90	$26.10	$159.00	7.98	48.86	1.16	1	7.65	8.62	4.98	3.73
Project 20	$3,864.70	$1,257.60	$1,458.70	15.46	249.98	1.86	1	9.48	9.34	12.64	5.21
Total	$25,058.80		$12,164.30	97.78			12	**80.68**	**81.77**	64.74	**39.27**
Profit/Rank	$256.28										
Profit*Score	$984,108.29	Maximize	<=$12500	<=100			x <=12			<=80	

Figure 37. Optimal Solution Budget with Twelve Programs

Figure 37 shows the optimal solution based on the efficient frontier and ROI. This solution will be covered in detail in the analysis section.

3. Real Options Valuation's Risk Simulator Data Analysis

The analysis of the risk simulator model shows, without a doubt, that there is a definite efficient frontier in which there is a substantial ROI limit in the profile used in this model. As shown in Figure 38 below, from \$9,500 to \$10,500 there is actually a decrease in the ROI maximization objective. From \$10,500 to \$12,500 there is a substantial increase in the EMV and ROI objectives with a rapid slow down in ROI above that threshold. Note that by increasing the budget by \$2,000 and allowing for additional programs, decision makers are given the "opportunity" to increase the Defense capabilities outlined in the NDS. This "opportunity" is one of the options available to Defense decision makers. The option does not have to be exercised, but it is available if needs dictate and funding is available from Congress. Other options include using eleven programs or thirteen programs, if funding becomes available, or even using nine programs in the case of budget cuts. Note that using nine programs provides an even better ROI than the baseline.

Static Efficiency Frontier

Budget	Comprehensive Score	Tactical Score	Military Score	Allowed Projects	ROI-RANK Objective	Percent Change ROI	
\$9,500.00	32.37	69.03	70.16	9	\$689,082.38	1.97%	
\$10,500.00	32.32	69.57	70.46	10	\$675,768.93	0.00%	Baseline
\$11,500.00	35.82	72.59	73.34	11	\$810,419.62	19.93%	
\$12,500.00	39.27	81.77	80.68	12	\$984,108.39	45.63%	
\$13,000.00	40.59	84.01	82.20	13	\$998,868.72	47.81%	

Figure 38. Efficient Frontier ROI from Baseline

This tells the decision makers in Washington that, based on the NDS, a budget of \$10,500 is not the most optimal to provide for our Defense needs. If more funding were allotted, the most optimal solution, based on strategic value, would be a budget of \$12,500 and twelve programs. Anything more would be a waste of taxpayers' money by funding a low ROI, and anything less would decrease the value of the Defense plan and make the budget less effective, while decreasing Defense capabilities.

Figure 39 shows the programs that were evaluated by name. The programs in green are programs selected at both the ten and twelve program optimization levels, while the programs in orange were specifically from the ten program optimization, and the programs in blue were from the twelve program optimization.

	Program	ENPV	NPV	Cost	Strategy Ranking	Military Score	Tactical Score	FTE Resoucres
P1	CH-47 Helicopter	$501.60	$102.30	$443.50	1.94	2.51	1.77	3.91
P2	Armed Reconnaissance Helicopter	$726.30	$121.30	$358.80	3.75	3.84	3.56	2.73
P3	Blackhawk Helicopter	$932.40	$354.20	$925.90	2.34	3.12	3.24	5.24
P4	Patriot Missle System	$620.50	$265.80	$512.10	1.36	5.14	5.1	3.41
P5	Patriot Modifications	$420.80	$271.20	$524.50	1.32	3.22	1.62	3.29
P6	F/A 18 E/F Fighter	$2,087.50	$345.90	$1,868.70	4.68	6.37	6.21	4.56
P7	Joint Strike Fighter	$3,264.90	$594.10	$1,602.10	10.59	8.69	7.53	4.23
P8	V22 Osprey	$2,563.40	$421.50	$2,133.40	2.83	2.64	4.12	5.61
P9	Carrier Replacement Program	$5,468.10	$1,032.20	$2,712.30	7.68	6.94	7.99	4.68
P10	DDG-1000 Program	$3,248.90	$775.40	$2,502.80	5.74	5.53	6.23	6.43
P11	Marine EOD Systems	$125.90	$32.80	$28.60	15.26	9.84	9.17	5.47
P12	Marine High Mobility Rocket System	$235.10	$85.60	$109.50	6.42	4.25	3.65	3.91
P13	Air Force F-22 Fighter	$4,163.50	$325.10	$3,054.20	5.26	3.41	6.21	5.23
P14	Air Force Joint Strike Fighter	$4,468.70	$594.10	$1,673.80	10.54	8.46	7.54	4.23
P15	V22 Osprey	$587.60	$421.50	$409.00	2.81	2.74	3.52	5.34
P16	Global Hawk Remote UAV	$1,698.40	$431.90	$658.30	11.92	8.45	8.87	4.26
P17	C5A Cargo Plane	$758.40	$134.20	$485.50	4.65	4.52	4.35	6.32
P18	C17 Cargo Plane	$1,248.30	$301.50	$331.50	4.85	6.13	5.62	3.57
P19	Defense Space Recon Program	$389.90	$26.10	$159.00	7.98	7.65	8.62	4.98
P20	Special Operations Command	$3,864.70	$1,257.60	$1,458.70	15.46	9.48	9.34	12.64

Figure 39. Real Programs by Name

Infigure 39, it is interesting to note that at the $10,500 level the program selected the DDG-1000 program and the Marine High Mobility Rocket System in addition to the other programs in green. This is based on the limited budget and EMVs utilized. At the other end of the spectrum, we have included more Patriot Missiles, Air Force and Marine V-22's and additional Special Operations personnel. It is obvious that the increased cost was one of the reasons they were not in the initial evaluation, but they bring a higher ROI to the Defense capability requirements. Additionally, it should be noted that both the DDG (Guided Missile Destroyer) program and the Marine High Mobility Rocket System have been dropped. In examining the data, it is obvious that the DDG program was too expensive and that the Marine High Mobility Rocket System did not provide a high enough return to be included in the Defense budget.

The programs that made the cut during both evaluations, the Joint Strike Fighter and the Global Hawk Unmanned Aerial Vehicle system, made the cut based on their capabilities rating and ability to meet the future needs of the Defense Department.

Programs not selected in either evaluation were either cost prohibitive or did not provide the capabilities required to meet security requirements. **Note:** The modeling data for @Risk is provided in Appendix B.

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III. RECOMMENDATIONS

A. GAO

The GAO recommends that the Secretary of Defense implement an enterprise-wide portfolio management approach to making weapon system investments that integrates the assessment and determination of war fighting needs with available resources and cuts across the services by functional or capability area (GAO, 2008). To ensure the success of such an approach, the Secretary should establish a single point of accountability at the Department level with the authority, responsibility, and tools to ensure that portfolio management for weapon system investments is effectively implemented across the Department. In addition, the Secretary should ensure that the following commercial best practices, identified in this report, are incorporated:

- Implement a review process in which needs and resources are integrated early and in which resources are committed incrementally based on the achievement of specific levels of knowledge at established decision points;
- Prioritize programs based on the relative costs, benefits, and risks of each investment to ensure a balanced portfolio;
- Require increasingly precise cost, schedule, and performance information for each alternative that meets specified levels of confidence and allowable deviations at each decision point leading up to the start of product development;
- Establish portfolio managers who are empowered to prioritize needs, make early go/no-go decisions about alternative solutions, and allocate resources within fiscal constraints; and
- Hold officials at all levels accountable for achieving and maintaining a balanced, joint portfolio of weapon system investments that meet the needs of the war fighter within resource constraints.

The GAO also recommends that the Secretary take steps to support Department-level decision makers and portfolio managers by developing a stronger joint analytical capability to assess and prioritize war fighting needs.

B. GARTNER GROUP

Gartner Group recommendations for end users implementing PA solutions include the following:

- Organizations seeking improved PPM should identify organizational and individual "readiness" to adopt the discipline of portfolio management, through a survey of capabilities and skills that are "foundational" to the use and application of portfolio management, before exploring which tools can best support and enhance PPM capabilities. In this way, they can help ensure that such projects are successful.
- Organizations should insist on modular, progressive implementations that will fit their immediate requirements, as well as supporting them as they evolve over time.
- Organizations should be prepared to invest in ongoing consulting support to ensure that the software is accepted by all stakeholders after implementation.
- Larger vendors will continue to be best-positioned to sustain themselves by cross-selling from large software portfolios to installed bases. These vendors' capability to reach down market to small and midsize businesses through established channel partners will increase. The market will see increased competition from alternative solutions, such as open source and Software as a Service, as many vendors expand product offerings and collide with other vendors.

C. RESEARCH TEAM

The authors of this paper offer the following recommendations:

- The PA toolsets are needed to make objective comparisons when working with choices containing numerous or complex input variables and unknown risk. As such, these tools are essential for project and program managers who are working with a multitude of projects or programs. Recommendation: NPS should explore the interest and potential for developing (or purchasing) a program management level curriculum for choosing and using PA and PM tools. The point of this curriculum would be to educate and indoctrinate future program managers in how to make defense management decisions based on acceptable risk levels utilizing PM guidance and PA decision making tools.
- The choices of PA tools are numerous, and selection criteria can be varied across organizations. As PA tools proliferate through DoD organizations there is a potential for implementation of a wide variety of (proprietary) PA tool suites, which would lead to costly support and interoperability issues. Recommendation: NPS should explore the potential for

development of a PA/PM Lab to be used for product evaluation, source selection criteria development, and making recommendations to defense officials on which products to support.

- A DoD umbrella organization is needed to establish policies, guidelines, best practices, and provide PA implementation planning assistance. Recommendation: Building upon the PA Lab concept in Recommendation "b", develop an NPS/PA Center of Excellence (CoE) in Monterey. This CoE would serve to coordinate and educate PA practitioners and provide a "Net Centric" environment to tie Joint PA efforts together. The CoE is part of the solution to satisfy the GAO recommendation: "The GAO also recommends that the Secretary take steps to support department-level decision makers and portfolio managers by developing a stronger joint analytical capability to assess and prioritize warfighting needs."

In summary, the recommendations are: 1) develop PA curriculum and education programs, 2) develop a PA solutions lab, and 3) develop a PA CoE.

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IV. CONCLUSIONS

A. COMPARING THE EVALUATION MODEL WITH REALITY

After developing the evaluation model, running simulations, and performing data analysis, the research team has concluded that Risk Simulator is a very capable Microsoft Excel plug-in which can evaluate program risk, evaluate EMVs, and optimize budgeting and programming constraints, all within the scope of the NDS. This software also has hundreds of risk models built in, including the military model. These models are easily modifiable to fit any number or programming requirements. To verify this assessment, refer to Figure 40, the original model with the real program names.

	Program	ENPV	NPV	Cost	Strategy Ranking	Military Score	Tactical Score	FTE Resoucres
P1	CH-47 Helicopter	$501.60	$102.30	$443.50	1.94	2.51	1.77	3.91
P2	Armed Reconnaissance Helicopter	$726.30	$121.30	$358.80	3.75	3.84	3.56	2.73
P3	Blackhawk Helicopter	$932.40	$354.20	$925.90	2.34	3.12	3.24	5.24
P4	Patriot Missle System	$620.50	$265.80	$512.10	1.36	5.14	5.1	3.41
P5	Patriot Modifications	$420.80	$271.20	$524.50	1.32	3.22	1.62	3.29
P6	F/A 18 E/F Fighter	$2,087.50	$345.90	$1,868.70	4.68	6.37	6.21	4.56
P7	Joint Strike Fighter	$3,264.90	$594.10	$1,602.10	10.59	8.69	7.53	4.23
P8	V22 Osprey	$2,563.40	$421.50	$2,133.40	2.83	2.64	4.12	5.61
P9	Carrier Replacement Program	$5,468.10	$1,032.20	$2,712.30	7.68	6.94	7.99	4.68
P10	DDG-1000 Program	$3,248.90	$775.40	$2,502.80	5.74	5.53	6.23	6.43
P11	Marine EOD Systems	$125.90	$32.80	$28.60	15.26	9.84	9.17	5.47
P12	Marine High Mobility Rocket System	$235.10	$85.60	$109.50	6.42	4.25	3.65	3.91
P13	Air Force F-22 Fighter	$4,163.50	$325.10	$3,054.20	5.26	3.41	6.21	5.23
P14	Air Force Joint Strike Fighter	$4,468.70	$594.10	$1,673.80	10.54	8.46	7.54	4.23
P15	V22 Osprey	$587.60	$421.50	$409.00	2.81	2.74	3.52	5.34
P16	Global Hawk Remote UAV	$1,698.40	$431.90	$658.30	11.92	8.45	8.87	4.26
P17	C5A Cargo Plane	$758.40	$134.20	$485.50	4.65	4.52	4.35	6.32
P18	C17 Cargo Plane	$1,248.30	$301.50	$331.50	4.85	6.13	5.62	3.57
P19	Defense Space Recon Program	$389.90	$26.10	$159.00	7.98	7.65	8.62	4.98
P20	Special Operations Command	$3,864.70	$1,257.60	$1,458.70	15.46	9.48	9.34	12.64

Figure 40. Evaluation Model with Real Program Names

On 6 April 2009, Secretary of Defense Gates held a press conference outlining the 2010 Defense Budget request. To the astonishment of Congress, the Defense Industrial Complex, and defense contractors it was announced that he planned to cut the F-22 fighter program, stop building the DDG-1000, increase production of the Joint Strike Fighter and increase the number of Special Operations personnel. These recommendations are directly in line with the evaluation results produced by Real

Options Valuation's Risk Simulator. Although there are some differences in the actual budget request and our evaluation, they would be consistent if we had known the EMV scoring used by the Secretary.

B. MODELING USING COTS PRODUCTS

Gartner and Forrester identified several PPM software suites which can be used to develop and manage project models. However, these models do not offer robust simulations which account for a range of probability distributions while accounting for risk across model scenarios. These products excel at providing graphical representations of complex data in the form of digital "dashboards," bubble-charts, and efficient frontiers. When used in conjunction with PA modeling software, these PPM suites are excellent at helping to efficiently manage large projects while helping to mitigate risk.

The authors of this paper found that the Real Options Valuation's Risk Simulator and @RISK were better suited for the research being conducted in accordance with the intent of this research paper. Risk Simulator was by far the superior product evaluated and provided hundreds of readymade models including; Military models, Efficient Frontier Models, multiple simulations. These modeling tools leverage the capabilities of Microsoft Excel and Monte-Carlo simulation to develop a range of statistical probability distributions using an array of variable inputs. This provides the ability to look at the best, worst and most likely scenarios.

C. RESEARCH LIMITATIONS

The authors found that the "boil the ocean" approach to evaluating products was beyond the scope that was executable in a (1) distributed team environment (i.e., team not collocated), and (2) without a central laboratory environment with configuration control of the products being evaluated. Additionally, it was difficult to codify all the numerous requirements and variables from multiple sources. The model was developed using only a few of the variables and requirements identified in Table 2. More complex models could be developed using the work in this document as a starting point.

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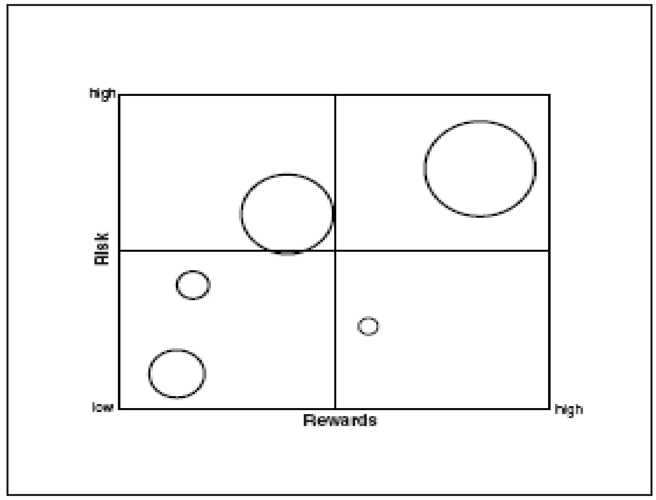
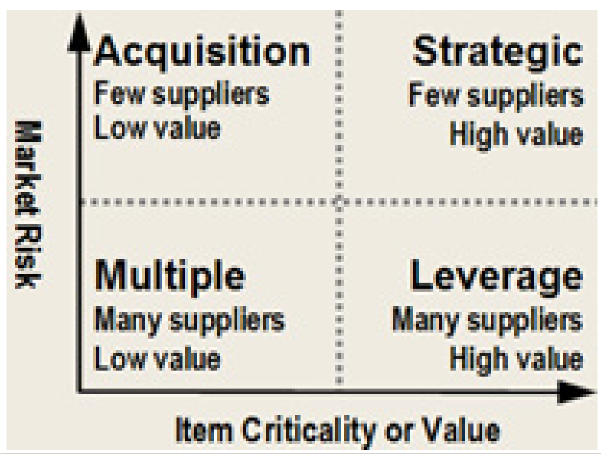
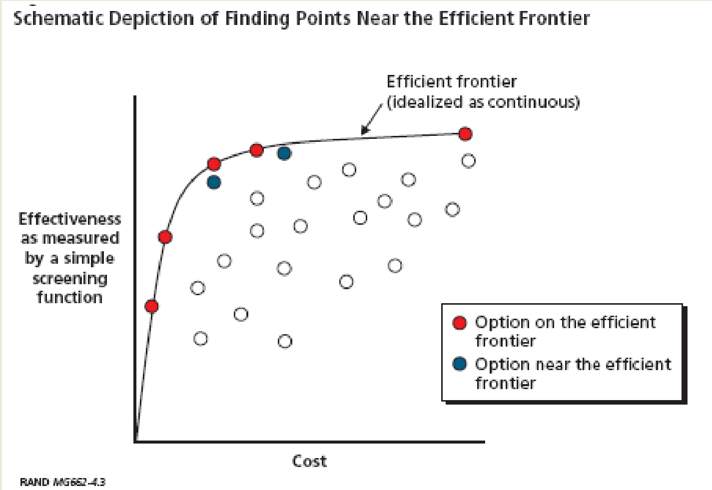
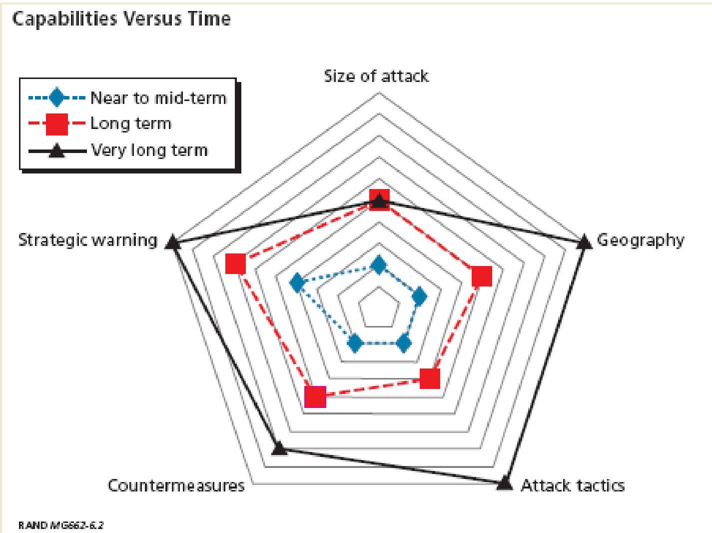
APPENDIX A. KEY REQUIREMENTS SOURCES

Table 3. Key Requirements Sources

Requirements Source	Author	Key Requirements
1. Dr. Flynn's research paper, brief, and Joint Applied Project Prompt	**Dr. Flynn**	**I. The 3 major goals of portfolio analysis as provided by Dr. Flynn are:** a) Value Maximization (focus is ROI) b) Balance - Short-term versus long-term, High-risk versus low-risk, across product categories, Basic research vs. production c) Strategic Direction **–** "On-strategy" **II. The major portfolio analysis requirements (top level) that have been identified are:** **1. Baseline Requirements:** a) Gather Life-Cycle cost data b) Establish Scoring System that determine how effectively systems match capabilities to requirements c) Develop way to display results to allow for both risk-reward analysis and trade-off and establish a Scoring System **2. Process Requirements to follow during analysis:** a) Maintain cognizance of the following inputs or constraints during Portfolio Analysis (see spreadsheet for particulars) b) Parameters to consider for achieving the Portfolio Analysis Goal of BALANCE (see spreadsheet for particulars) c) Requirements during the process of Maximizing Value phase (see spreadsheet for particulars) d) Scorecard process/contents requirements (see spreadsheet for particulars)
2. DoDD 7450.20 directive mandating use of PA in DoD systems	**SECDEF reference (c)**	**I. Use the Joint Capability Area common framework and lexicon for the organization of capability portfolios** **II. Cover material and non-material investments** **III. Leverage operational expertise of Combatant Commands**

Requirements Source	Author	Key Requirements
3. GAO Report on PA Best Practices	**GAO reference (b)**	**Use of risk/reward "bubble diagram** Figure 4: Risk Versus Rewards Matrix  Source: GAO.
4. Use of PA in Logistics Planning Scenarios	**Defense Acquisition University reference (d)**	Classify every purchase or family of purchases into one of four categories or quadrants: acquisition, multiple, leverage, or strategic; 

Requirements Source	Author	Key Requirements
5. Portfolio Analysis Methods	**RAND reference (i)**	
6. Portfolio Analysis Methods	**RAND reference (i)**	
7. Project Management Body of Knowledge – Functional Dimensions	**Project Management Institute**	**I. Time management** — Manages deliverable activity timelines and deadlines for programs, projects, tasks and assignments **II. Resource management** — Manages allocation of available personnel using a resource profile repository, and allows resource loading and leveling (natively, or at minimum via third-party tool integration) **III. Cost management** — Tracks resource (and, often, other) costs and facilitates chargeback or billing of project expenses; for example, those associated with time, travel, equipment or other material

<table>
<tr><th>Requirements Source</th><th>Author</th><th>Key Requirements</th></tr>
<tr><td></td><td></td><td>IV. Integration (portfolio) management — Provides business intelligence to improve portfolio alignment, planning, and project or service delivery. Dashboard tools provide an integrated view of program and project status, resource capacity, service levels, strategic alignment, and more. Integration can also be to back-office systems. Gathers portfolio data from these segments to let users manage their pipelines, report and forecast project progress, and perform portfolio analysis and prioritization.</td></tr>
<tr><td>8. “Assessing Risks and Returns: A Guide for
Evaluating Federal Agencies’ IT Investment Decision-Making,”</td><td>GAO reference (q)</td><td>
<table>
<tr><th>Project Name</th><th>Estimated Project Costs/ Year</th><th>Strategic Alignment
25 pts. total</th><th>Mission Effectiveness
20 pts. total</th><th>Organizational Impact
10 pts. total</th><th>Risk
20 pts. total</th><th>Benefit/ Cost Ratio
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<tr><td>Project XXXXXX</td><td>898K</td><td>11</td><td>10</td><td>7</td><td>11</td><td>10</td><td>49</td><td></td></tr>
<tr><td>Project XXXXXX</td><td>898K</td><td>6</td><td>8</td><td>3</td><td>5</td><td>5</td><td>27</td><td></td></tr>
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</td></tr>
<tr><td>9. “Assessing Risks and Returns: A Guide for
Evaluating Federal Agencies’ IT Investment Decision-Making,”</td><td>GAO reference (q)</td><td>B. ORGANIZATIONAL IMPACT (relative weight = 10 points) Measures the impact n organizational personnel of the system. The more favorable the impact on the organization the higher its score.

B.1. Personnel and Training (3 of 10 points) Assess the impact of the system on the knowledge, skill, and training of organizational personnel if the system in implemented. Score from zero to three based on the scale below:

Zero Points: System is likely to require significant new skills to operate and support and the project does not appear to mitigate this impact through appropriate training, changes in rating qualifications, etc.

Three Points: System is an improvement to an existing system and will require relatively little new skill and/or knowledge to operate or support. If it is a new system, it will introduce valuable new skills and knowledge to the organization and the project will mitigate any adverse impact through appropriate training, planning for rating qualification changes, etc.</td></tr>
</table>

Requirements Source	Author	Key Requirements
		B.2. Scope of Beneficiaries/ Cross-Functional (4 of 10 points). Assess a higher score (zero to four) the broader the scope of beneficiaries. Zero Points: Limited number of beneficiaries. This system will be used by only one office in headquarters, a single area, or district. Not a cross-functional system. Four Points: System is cross-functional and serves a number of offices, areas, and/or districts. System will be used by a large number of organizational units. System will be used by the public. **B.3. Quality of Work Life** (3 of 10 points). Measures the improvement in quality of work life expected for the systems. Score higher (zero to three points) the more work life improvement is expected. Zero Points: Little if any positive impact on the quality of work life. System may increase the work required (e.g., additional data entry). Three Points: Positive contribution to the quality of work life will clearly result. For example, the system will improve medical care for dependents or allow a job to be done much faster such that job satisfaction will increase.
		C. MISSION EFFECTIVENESS (relative weight = 20 points). Measures the impact of the system on both external and internal customers. It is a measure of the system's ability to improve the performance of support or operational programs. This improvement should be measured in quantitative terms, but not in dollars. The economic (dollar) impact is captured in the benefit/ cost ratio. However, the same benefits might be measured here in a different manner. For example, improvements might be expressed in terms of accomplishing a task sooner (hours or minutes), delivering a service with fewer mistakes, increasing the availability of a computer system for customer use (hours per month saved in time for system backups), or a number of similar terms. The more the project or system improves mission effectiveness the higher the score. **C.1. Improve Internal Program Services** (10 of 20 points). Assess the expected improvement in service to internal customers. For example the system might improve

Requirements Source	Author	Key Requirements
		the timeliness of financial reporting throughout the organization. Score (zero to ten) higher, the more that service will be improved in response to a problem expressed by users of the service. Zero Points: System does not appear to meet a problem defined by an internal customer. Little improvement in important customer service criteria, such as timeliness, quality, or availability is expected. An improvement is described but not quantified. Ten Points: A significant improvement expected in areas such as timeliness, quality, or availability and the improvement is quantified. The improvement also addresses an important problem or area of service improvement defined by the customer. **C.2. Improved Service to the Public** (10 of 20 points). Assess the expected improvement in service to the public. Score (zero to ten) higher, the more improvement is anticipated in response to a requirement defined by the public. Zero Points: System appears to provide little or no direct improvement in service to the public. Systems may make a small improvement in timeliness, quality, or availability, but there is no documented need for such an improvement. The improvement is not quantified. Ten Points: System significantly improves service to the public in a mission where need is demonstrated or provides a new type of service to meet changing customer demands. The improvement is quantified.
		D. STRATEGIC ALIGNMENT (relative weight = 25 points**).** Measures to what extent the proposed investment supports strategic organizational objectives. Scoring is based primarily on explicit documentation of the need for the Integrated Risk Management (IRM) system in planning documents. The more the project or system is aligned with program/strategic goals, the higher the score. **D.1. Business Model** (7 of 25 points). Assess the degree of alignment with the organization’s business model.

Requirements Source	Author	Key Requirements
		Zero Points: Proposed project or system does not support organizational products/services or processes identified in the business model. One to Four Points: Proposed system is specifically mentioned in the 5-year IRM plan and supports organizational products/services or processes identified in the business model. (Score one to two points if the system supports products/services or processes in the business model, but is not listed in the 5-year IRM plan.) Five to Seven Points: Proposed system is specifically mentioned in the 5-year IRM plan and supports products/services or processes identified in the business model, and the project has been coordinated with all offices identified by the model for the respective processes the system supports. **D.3. Business Process Redesign** (6 of 25 points). Assess the degree this system enables the organization to do business in a better way. Score (zero to six) higher the greater the expected improvement. Zero Points: This system automates an existing business process with little improvement of the process (i.e., helps to do the same thing faster). Six Points: System enables a significant improvement in the way business is conducted **D.2. Level of Interest** (12 of 25 points). Assess the level of interest by senior managers (at agency and departmental level) and/or the Congress. Score (zero to twelve) higher the greater the level of interest. Zero Points: No expressed support for this system by senior managers or the Congress. Twelve Points: System has strong support from the Congress, departmental senior managers, and/or the head of the agency. System is specifically mentioned in determinations.
		E. BENEFIT-COST IMPACT(S) (relative weight = 25 points). Measures the value of the system in dollar terms. The system benefit/cost ration is the key indicator. This ration is developed using the standard benefit-cost guidance

Requirements Source	Author	Key Requirements
		and spreadsheet promulgated by the organization. The standard guidance ensures all system studies include a common set of costs and approach benefits definition in a similar manner. The standard spreadsheet assists system sponsors in the benefit/cost calculation. The higher the benefit/cost ratio, the better the score. Zero Points: Any benefit/cost ratio less than one (i.e., costs exceed the benefits). One Point: Benefit/cost ratio of one. Five Points: Benefit/cost ratio of 1.5 to 1.75. Ten Points: Benefit/cost ratio of 1.76 to 1.99. Fifteen Points: Benefit/cost ratio of 2.0 to 2.99. Twenty Points: Benefit/cost ratio of 3.0 to 3.99. Twenty-five Points: Benefit/cost ratio of 4.0 or greater

APPENDIX B. PALISADE @RISK MODELING DATA AND ANALYSIS

A. PALISADE @RISK MODELING DATA

In this model, the user provides the Project Name, the Budget for the project, and then provides Minimum, Most Likely (ML) and Maximum budget values. The individual project percentages should reflect of the actual cost associated with the project as represented by the ML and Maximum budget overruns expected. This model could be enhanced with additional variables representing project risk, or ranges of risk represented as Min/ML/Max values. The user may change any of the light green shaded cells, which are the model's inputs; the significant model outputs are shaded in light blue.

1. @RISK Model using Minimum, Most Likely (ML) and Maximum Budget Values

Table 4. Budget Simulation

Project	Budget	Min	ML	Max	Min$	ML$	Max$	Budget Simulation 1000 Iterations
Project 1	$1,732.44	100%	110%	125%	$ 1,732.44	$ 1,905.68	$ 2,165.55	$ 1,920.12
Project 2	$859.00	100%	110%	125%	$ 859.00	$ 944.90	$ 1,073.75	$ 952.06
Project 3	$1,845.00	100%	110%	125%	$ 1,845.00	$ 2,029.50	$ 2,306.25	$ 2,044.88
Project 4	$1,645.00	100%	110%	125%	$ 1,645.00	$ 1,809.50	$ 2,056.25	$ 1,823.21
Project 5	$458.00	100%	110%	125%	$ 458.00	$ 503.80	$ 572.50	$ 507.62
Project 6	$52.00	100%	110%	125%	$ 52.00	$ 57.20	$ 65.00	$ 57.63
Project 7	$758.00	100%	110%	125%	$ 758.00	$ 833.80	$ 947.50	$ 840.12
Project 8	$115.00	100%	110%	125%	$ 115.00	$ 126.50	$ 143.75	$ 127.46
Project 9	$125.00	100%	110%	125%	$ 125.00	$ 137.50	$ 156.25	$ 138.54
Project 10	$458.00	100%	110%	125%	$ 458.00	$ 503.80	$ 572.50	$ 507.62
Project 11	$45.00	100%	110%	125%	$ 45.00	$ 49.50	$ 56.25	$ 49.88
Project 12	$105.00	100%	110%	125%	$ 105.00	$ 115.50	$ 131.25	$ 116.38
Project 13	$48.00	100%	110%	125%	$ 48.00	$ 52.80	$ 60.00	$ 53.20
Project 14	$351.00	100%	110%	125%	$ 351.00	$ 386.10	$ 438.75	$ 389.03
Project 15	$421.00	100%	110%	125%	$ 421.00	$ 463.10	$ 526.25	$ 466.61
Project 16	$124.00	100%	110%	125%	$ 124.00	$ 136.40	$ 155.00	$ 137.43
Project 17	$521.00	100%	110%	125%	$ 521.00	$ 573.10	$ 651.25	$ 577.44

Project	Budget	Min	ML	Max	Min$	ML$	Max$	Budget Simulation 1000 Iterations
Project 18	$512.00	100%	110%	125%	$ 512.00	$ 563.20	$ 640.00	$ 567.47
Project 19	$5.00	100%	110%	125%	$ 5.00	$ 5.50	$ 6.25	$ 5.54
Project 20	$21.00	100%	110%	125%	$ 21.00	$ 23.10	$ 26.25	$ 23.28
Total	$ 10,200.44				$ 10,200.44	$ 11,220.48	$ 12,750.55	$ 11,305.48

The distribution curve for the budget simulation is shown in Table 4 above. This model uses the previous results from 1000 simulations to arrive at a 90% probability that the projects can be executed at a budget cost (Simulated Budget) of $11,514, or a delta cost increase of $1,314 from the budget baseline of $10,200 (Figure 41).

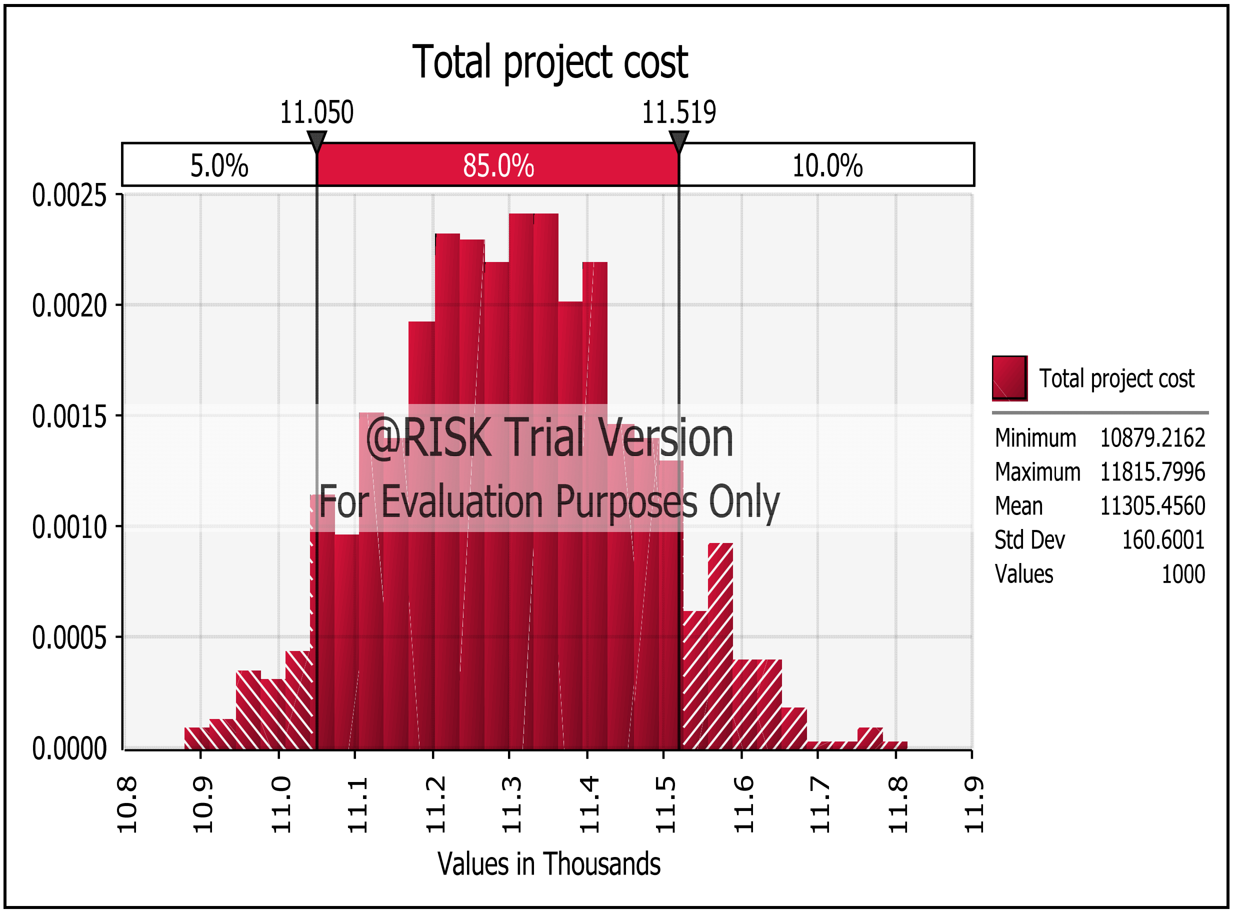

Figure 41. Cost Probability Distribution

Building upon the results of the previous model, in the next model, Table 5, the Project Name and the Mean Budget Simulation are inherited from the previous model. New columns for Strategic Value, Tactical Value and FTE Resources are added. These columns are scores (which would be) provided by a panel of military experts which can be considered a Delphi panel; for this model, the scores were determined by the authors. The simple addition of these the Delphi scores are added to create an overall KVA score. The EMV is then calculated by dividing the KVA with the simulated budget value. The EMV is now akin to a ROI which is used to evaluate and rank commercial projects. Note that the Value scores are not weighted in this model.

2. @RISK Model using Strategic, Tactical and FTE Resource values

Table 5. Expected Military Value

Projects	Budget Simulation	Strategic Value	Tactical Value	FTE Resources	KVA Scores	EMV (KVA/Budget)
Project 1	$1,920.12	8.10	2.31	1.20	11.61	0.605%
Project 2	$952.06	1.27	4.83	2.50	8.60	0.903%
Project 3	$2,044.88	9.88	4.75	3.60	18.23	0.892%
Project 4	$1,823.21	8.83	1.61	4.50	14.94	0.819%
Project 5	$507.62	5.02	6.25	5.50	16.77	3.303%
Project 6	$57.63	3.64	5.79	9.20	18.63	32.333%
Project 7	$840.12	5.27	6.47	12.50	24.24	2.885%
Project 8	$127.46	9.80	7.16	5.30	22.27	17.469%
Project 9	$138.54	5.68	2.39	6.30	14.37	10.371%
Project 10	$507.62	8.29	4.41	4.50	17.20	3.389%
Project 11	$49.88	7.52	4.65	4.90	17.07	34.216%
Project 12	$116.38	5.54	5.09	5.20	15.83	13.603%
Project 13	$53.20	2.51	2.17	4.60	9.28	17.440%
Project 14	$389.03	9.41	9.49	9.90	28.80	7.403%
Project 15	$466.61	6.91	9.62	7.20	23.73	5.085%
Project 16	$137.43	7.06	9.98	7.50	24.55	17.860%
Project 17	$577.44	1.25	2.50	8.60	12.35	2.138%
Project 18	$567.47	3.09	2.90	4.30	10.29	1.813%
Project 19	$5.54	5.25	1.22	4.10	10.57	190.741%
Project 20	$23.28	2.01	4.06	5.20	11.27	48.421%
Total	$ 11,305.48					

In this model, the values are inherited from the previous two models. The model is then sorted in descending sequence by EMV.

3. @RISK Model Sorted by EMV

Table 6 below shows the top ranked EMV. The key aspects for the models are the expected budget values, and the scores provided by the Delphi panel of experts. The validity of the input values is critical to obtaining usable results from these @RISK models.

Table 6. Top Ranked EMV

Programs	Budget Simulation	KVA Scores	EMV (KVA/Budget)
Project 19	$5.54	10.57	190.741%
Project 20	$23.28	11.27	48.421%
Project 11	$49.88	17.07	34.216%
Project 6	$57.63	18.63	32.333%
Project 16	$137.43	24.55	17.860%
Project 8	$127.46	22.27	17.469%
Project 13	$53.20	9.28	17.440%
Project 12	$116.38	15.83	13.603%
Project 9	$138.54	14.37	10.371%
Project 14	$389.03	28.80	7.403%
Project 15	$466.61	23.73	5.085%
Project 10	$507.62	17.20	3.389%
Project 5	$507.62	16.77	3.303%
Project 7	$840.12	24.24	2.885%
Project 17	$577.44	12.35	2.138%
Project 18	$567.47	10.29	1.813%
Project 2	$952.06	8.60	0.903%
Project 3	$2,044.88	18.23	0.892%
Project 4	$1,823.21	14.94	0.819%
Project 1	$1,920.12	11.61	0.605%
Total	$ 11,305.48		

4. Palisade @RISK Data Analysis

This section provides graphical representations of the preceding data tables, and provides analysis of the information. The graphics in Figure 42 and Figure 43 compare the original budget values with the simulated budget values following 1,000 Monte Carlo simulation iterations. The delta between the budgets (original vs. simulated) is driven by the low, most-likely and maximum cost values provided to the model.

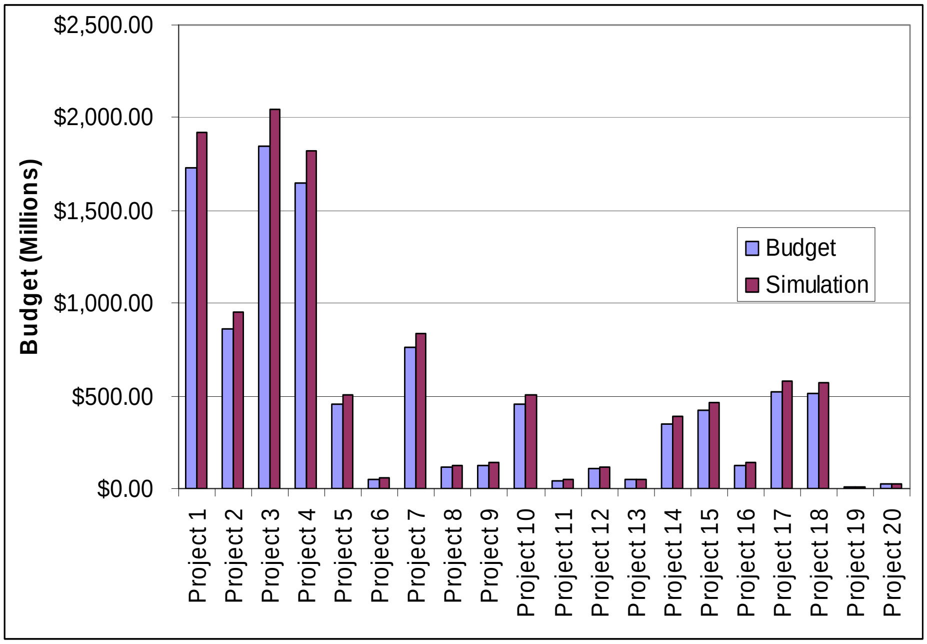

Figure 42. Budget (Original vs. Simulated #1)

The graphic in Figure 44 compares the project cost (Sim$) with the EMV for each project. Projects where the EMV point is above the Sim$ point are the most favorable from an EMV perspective. In this particular simulation, the highest cost projects appear to have the least return (based upon the notional weighting applied to the KVA).

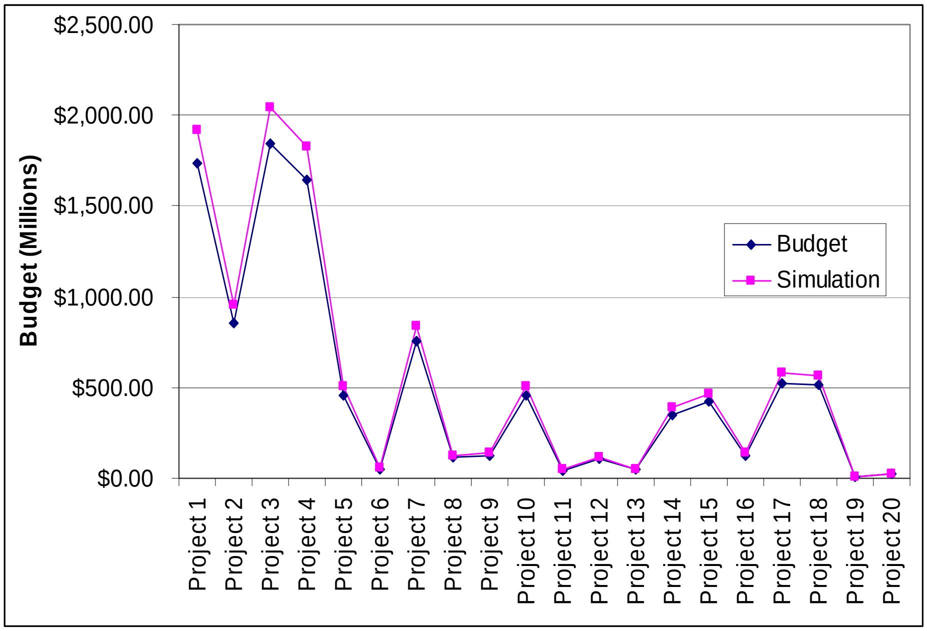

Figure 43. Budget (Original vs. Simulated #2)

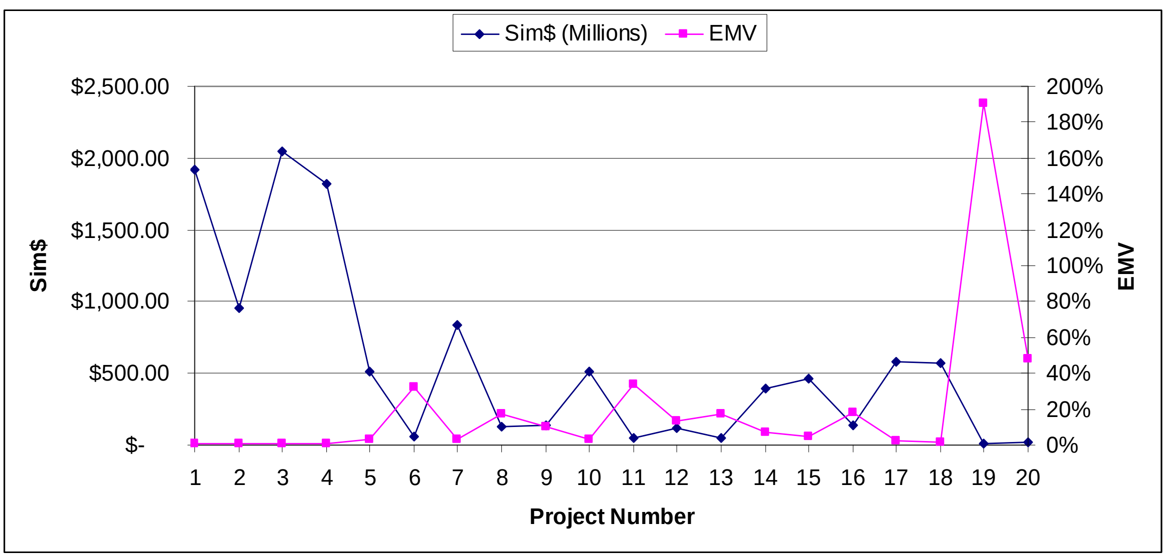

Figure 44. Project Cost (Sim$) Compared with EMV

The graphic in Figure 45 stratifies the EMV low to high. In this simulation, only (4) projects (#6, 11, 20, 19) have an EMV greater than 20%.

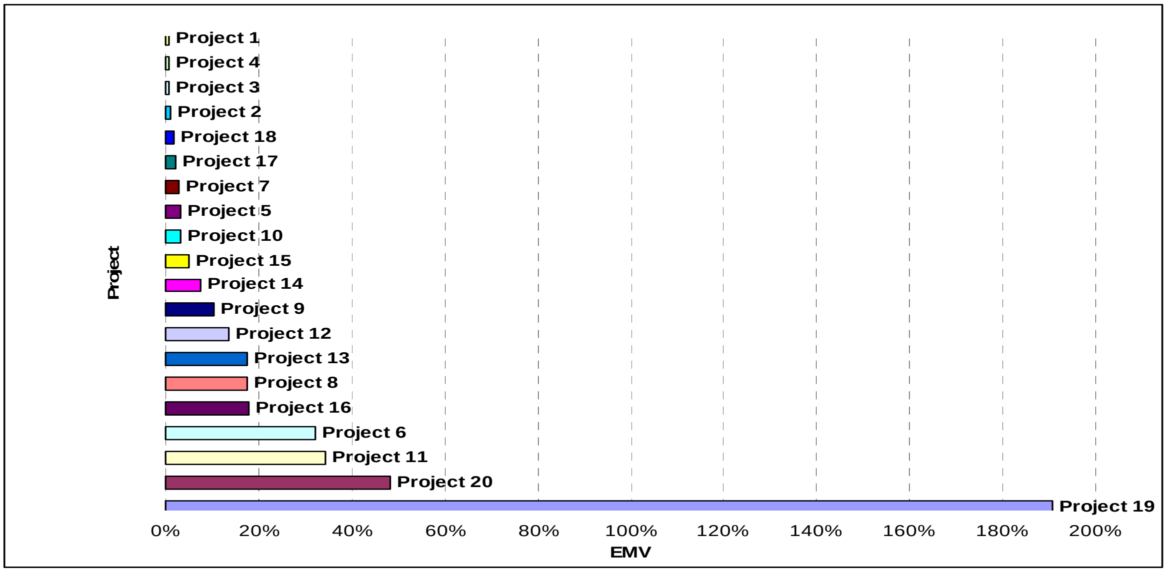

Figure 45. Project EMV Low to High

While this model seems to provide for a solution to the original model, it in fact does not. The different models are not integrated with each other which does not allow for a continuous simulation, optimization cycle that is required to create a valid efficient frontier. This would be one of the software programs used by the NPS PA CoE to evaluate the possibility of being utilized for future implementation, though at this time, it is not a viable candidate for evaluating defense acquisition capability requirements.

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APPENDIX C. CREATION OF AN EFFICIENT FRONTIER

Using Risk Simulator to create an efficient frontier is easily accomplished. As depicted in Figure 46, select any green cell (A) in the model (these are already set up Monte Carlo simulation assumptions). Reset or set new assumptions by clicking on Risk Simulator, Set Input Assumptions (B) and selecting the desired distribution. In this case, select Triangular (C) and enter in the desired Minimum, Likely, and Maximum values (C).

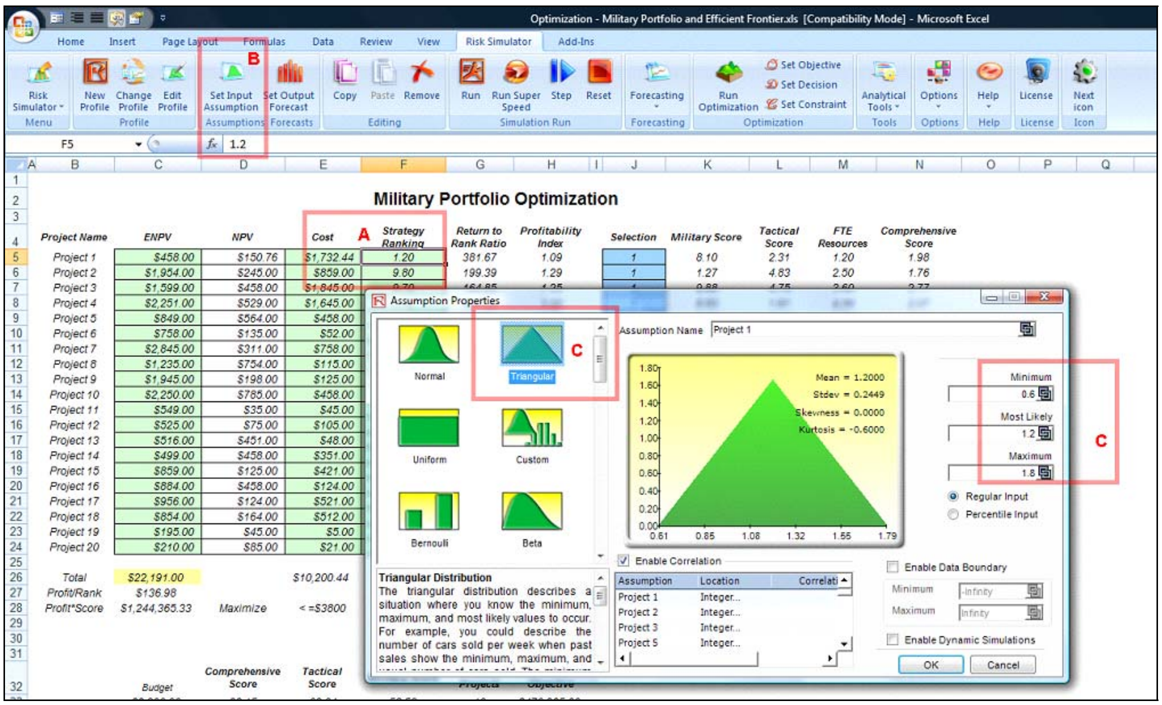

Figure 46. Efficient Frontier Setting Assumptions

Next, select the desired output. In the example depicted in Figure 47, cell C26 (D) is the total NPV for the portfolio (EMV can also be selected if desired). Click on Set Output Forecast (E) and give provide a name (F). Run Simulation or Run Super Speed (G), which displays chart (H). Set the probability of exceeding or being below some value (H). You can then analyze the Statistics tab to look at all the risk factors and risk coefficients (e.g., coefficient of variation). You can also see a two tail or left tail boundary, as well as adjust the percent of certainty in the chart.

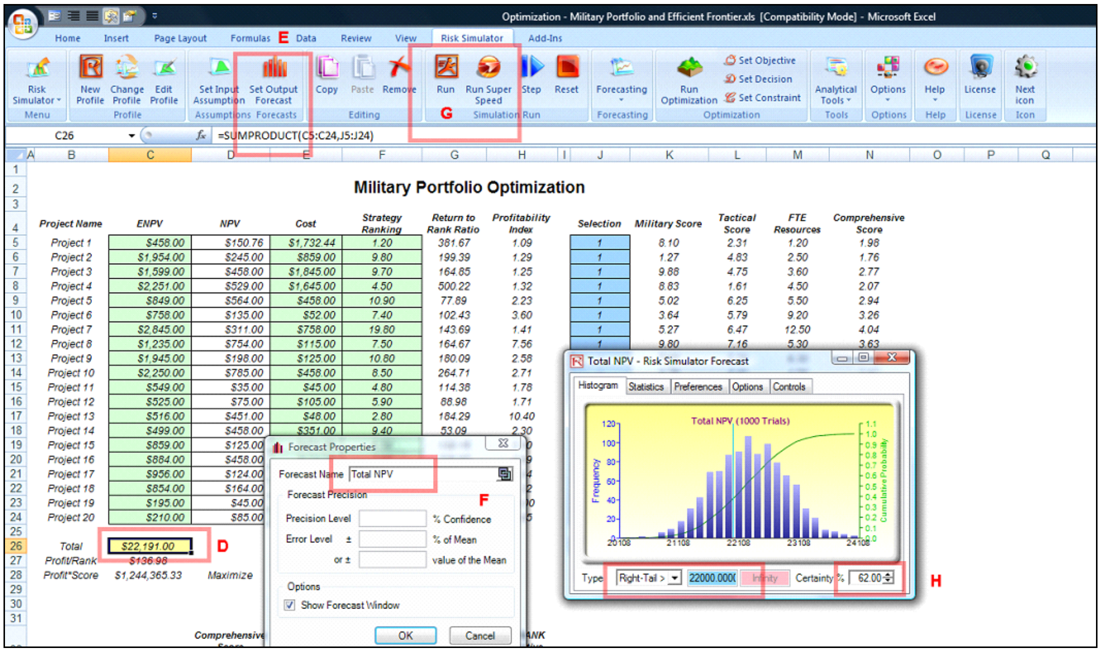

Figure 47. Setting the Output

Now you are ready to run the optimization (I) in Figure 48. Here you can select the Static, Dynamic or Stochastic Optimization routine (K). As shown in (K) below, simulation is tied into the optimization routines (i.e., these two items cannot be separated into two different applications). When optimizing using either the Dynamic or Stochastic routines, you will need to simulate, optimize, and then repeat multiple times.

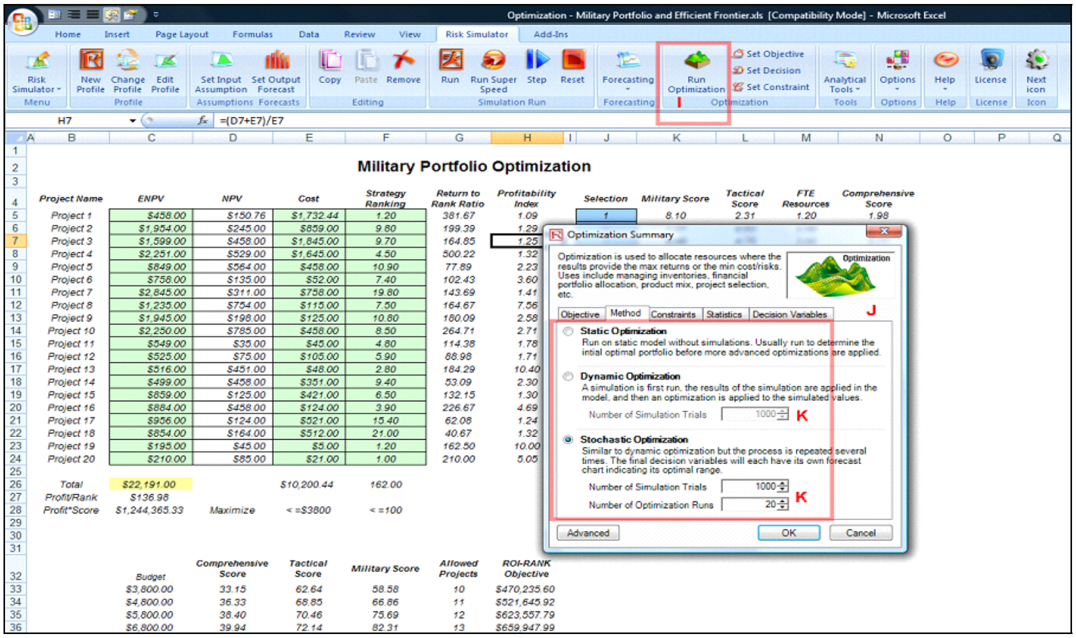

Figure 48. Starting Optimization

As shown in (L) below in Figure 49 you can also set constraints, then run the optimization model (M) again to add in the Efficient Frontier (N) by selecting the constraints of interest (O) and adding them to the changing constraints list to run the efficient frontier.

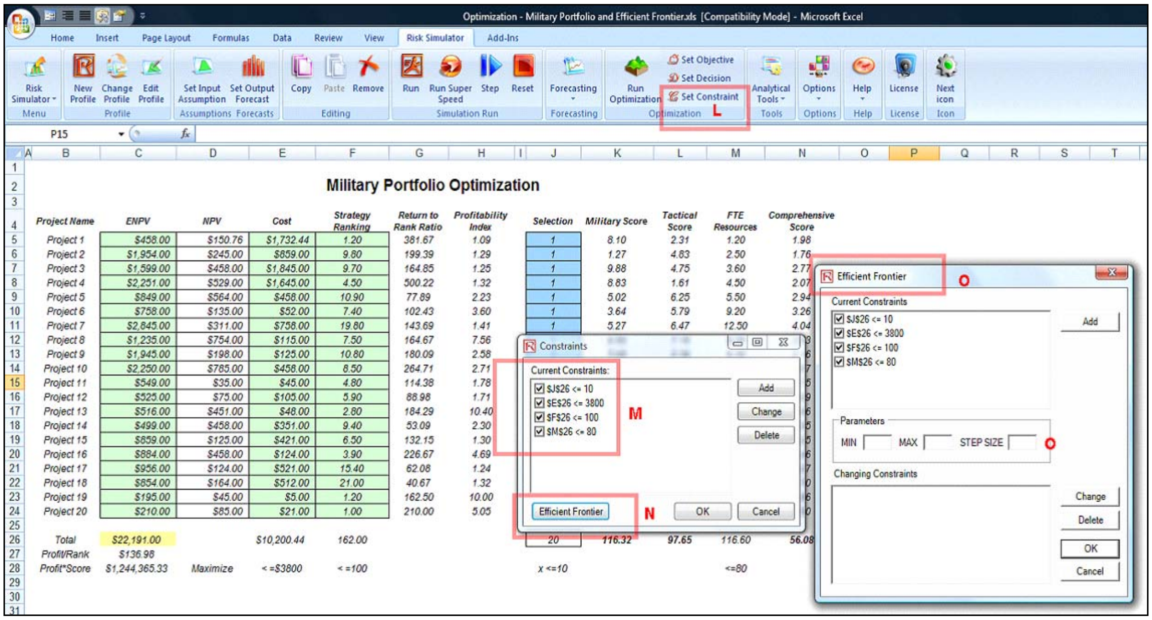

Figure 49. Setting Constraints

The efficient frontiers generated by the optimization illustrate the best combination and permutation of projects in the optimal portfolio. Each point on the frontier is a portfolio of various combinations of projects that provide the best allocation possible given the requirements and constraints (Mun & Housel, 2006, p. 12). Because this is an integrated process, simulated and optimized in sequence, together, the analysis will also be integrated, which is why it is called Integrated Risk Management (IRM). Since the process is integrated, it cannot be taken apart to allow some parts to be done one way and other parts to be done in another way and then merged back together. If the analysis is performed in a way that is not integrated, the results will be erroneous.

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